NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

THE IMPACT OF DEPLOYMENT RATES ON THE
EFFECTIVENESS OF STRATEGIC DEFENSES

by

Frederick W. Weber, Jr.

September 1987

Thesis Advisor: E. B. Rockower

CURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

1b RESTRICTIVE MARKINGS

2a SECURITY CLASSIFICATION AUTHORITY

2b DECLASSIFICATION / DOWNGRADING SCHEDULE

3 DISTRIBUTION/AVAILABILITY OF REPORT
Approved for public release; distribution is unlimited.

4 PERFORMING ORGANIZATION REPORT NUMBER(S)

5 MONITORING ORGANIZATION REPORT NUMBER(S)

6a NAME OF PERFORMING ORGANIZATION
aval Postgraduate School

6b OFFICE SYMBOL (If applicable)
55

7a NAME OF MONITORING ORGANIZATION
Naval Postgraduate School

6c ADDRESS (City, State, and ZIP Code)
Monterey, California 93943-5000

7b ADDRESS (City, State, and ZIP Code)
Monterey, California 93943-5000

8a NAME OF FUNDING/SPONSORING ORGANIZATION

8b OFFICE SYMBOL (If applicable)

9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c ADDRESS (City, State, and ZIP Code)

10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification) The Impact Of Deployment Rates On The Effectiveness of Strategic Defenses

12 PERSONAL AUTHOR(S) WEBER, Frederick W. Jr.

13a TYPE OF REPORT
Master's Thesis

13b TIME COVERED
FROM ______ TO ______

14 DATE OF REPORT (Year, Month, Day)
1987 September

15 PAGE COUNT
65

16 SUPPLEMENTARY NOTATION

17 COSATI CODES

FIELD	GROUP	SUB-GROUP

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Ballistic Missile Defense, Strategic Defense, Deployment Rates, Kinetic Kill Vehicles, Boost-Phase, Deployment Planning, Fast-Burn Boosters

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The effectiveness of a Ballistic Missile Defense layer of Space-ased Kinetic Kill Vehicles is examined relative to a threat with ncreasing numbers of Fast-Burn Boosters over the years 1994-2004. A ethodology for evaluating Ballistic Missile Defense layer effectiveness nd required deployment rates over time is developed.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS

21 ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED

22a NAME OF RESPONSIBLE INDIVIDUAL
Prof. E. B. Rockower

22b TELEPHONE (Include Area Code)
408-646-2191

22c OFFICE SYMBOL
55 Rf

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

The Impact of Deployment Rates on the Effectiveness of Strategic Defenses

by

Frederick W. Weber, Jr.
Captain, United States Army
B.S., United States Military Academy, 1977

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1987

ABSTRACT

The effectiveness of a Ballistic Missile Defense layer of Space-Based Kinetic Kill Vehicles is examined relative to a threat with increasing numbers of Fast-Burn Boosters over the years 1994-2004. A methodology for evaluating Ballistic Missile Defense layer effectiveness and required deployment rates over time is developed.

THESIS DISCLAIMER

This thesis is a preliminary analysis of the effects of deployment rates on the overall effectiveness of a strategic defense. The thesis uses one basic set of assumptions about a possible threat and a possible defense. Although a model developed at RAND was used to obtain data on which the analysis could be based, **this is not a RAND product.**

It is not intended that this work itself be the basis of policy decisions but that other analysts may wish to extend and use what is presented here. By using various threat forecasts and defense system parameters, it will be possible to determine the true impact of deployment decisions on the effectiveness of a strategic defense.

DEPARTMENT OF DEFENSE

COMMAND, CONTROL, COMMUNICATIONS COUNTERMEASURES (C3CM) JOINT TEST FORCE
KIRTLAND AIR FORCE BASE, NEW MEXICO 87117-5000

REPLY TO ATTN OF: OAM (CPT Weber, 505-846-6840, AV 246-6840) 13 January 1988

SUBJECT: Thesis Erratum

TO: SEE DISTRIBUTION LIST

There is an error in the thesis "The Impact of Deployment Rates on the Effectiveness of Strategic Defenses," by Frederick W. Weber, Jr., Naval Postgraduate School, Monterey, CA, September 1987. In Figure 3.5 on page 31, one of the axes is labelled "100'S OF SBKKV." It should read "1000'S OF SBKKV," or, equally correctly, "100'S OF PLATFORMS."

FWeber

F. WEBER
Captain, U.S. Army

Dr. Louis C. Marquet
Deputy for Technology
Strategic Defense Initiative Organization
The Pentagon
Washington, DC 20301-7100

Strategic Defense Initiative Organization
ATTN: SDIO-S (LTC Wayne K. Murphy)
The Pentagon
Washington, DC 20301-7100

Dr Michael Miller
The RAND Corporation
1700 Main Street
Santa Monica, CA 90406

Mr Timothy Webb
The RAND Corporation
2100 M Street, N.W.
Washington, DC 20037-1270

Mr Thomas Morgan, L86
Lawrence Livermore National Laboratory
P.O. Box 808
Livermore, CA 94550

Mr John Lawton
Naval Surface Weapons Center
Dahlgren, VA 22448

Dr Maile Smith
Science and Technology Division
Institute for Defense Analyses
1801 North Beauregard Street
Alexandria, VA 22311

CPT (P) F.W. Weber, Jr.
C3CM JTF/USA Elm
Kirtland AFB, NM 87117-5000

Mr Troy Crites, M7/597
The Aerospace Corporation
P.O. Box 92957
Los Angeles, CA 90009

DISTRIBUTION:

Defense Technical Information Center
Cameron Station
Alexandria, VA 22304-6145

Library, Code 0142
Naval Postgraduate School
Monterey, CA 93943-5002

Professor E.B. Rockower, Code 55Rf
Department of Operations Research
Naval Postgraduate School
Monterey, CA 93943-5000

Professor B. Neta, Code 53Nd
Department of Mathematics
Naval Postgraduate School
Monterey, CA 93943-5000

Professor P. Purdue, Code 55Pd
Department of Operations Research
Naval Postgraduate School
Monterey, CA 93943-5000

Professor H. Fredricksen, Code 53Fs
Department of Mathematics
Naval Postgraduate School
Monterey, CA 93943-5000

Professor K. Woehler, Code 61Wh
Department of Physics
Naval Postgradute School
Monterey, CA 93943-5000

Professor M.G. Sovereign, Code 55Sm
Department of Operations Research
Naval Postgradute School
Monterey, CA 93943-5000

Professor C. Jones, Code 54Js
Department of Administrative Sciences
Naval Postgraduate School
Monterey, CA 93943-5000

Professor J. Sternberg, Code 56Sn
Department of National Security Affairs
Naval Postgraduate School
Monterey, CA 93943-5000

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

A debt of gratitude is owed to Dr. Michael Miller of the RAND Corporation for the use of his time and model to generate the initial data required for this study. Mr. Thomas Morgan of the Lawrence Livermore National Laboratory provided useful insights into the nature of Fast-Burn Boosters. Travel to support this study was funded by a Naval Surface Weapons Center contract with the Mathematics Department of the Naval Postgraduate School.

I. INTRODUCTION

A. PURPOSE AND OBJECTIVES

Much of the recent public discussion of the Strategic Defense Initiative has been of the nature of "What can we build and how soon can we build it?" This thesis will illuminate the question "If we think we know what we want to build, how fast should we build it?" It is not the intention here to give the definitive answer to this question, but to offer a methodology for answering it. This thesis will consider appropriate measures of effectiveness (MOEs)[1] for a boost-phase strategic defense layer, develop a model which can be used to evaluate deployment decisions for such a layer, present sample results, and offer conclusions and recommendations for future planning. Although the methodology is demonstrated here for a space-based layer consisting of kinetic kill vehicles (KKV), it is generally applicable to different systems and defense layers.

B. BACKGROUND

1. Policy

The United States currently has no defense against ballistic missile attack. On 23 March 1983, President Reagan called for a concerted effort by America's scientific and engineering community to find a way to render such missiles "impotent and obsolete." [Ref. 1] The U.S. effort to meet the President's request is known as the Strategic Defense Initiative (SDI), and the Defense Department agency created to consolidate and carry forward the various ballistic missile defense (BMD) programs of the individual Armed Services is the Strategic Defense Initiative Organization (SDIO). In its 1986 Report to the Congress, the SDIO stated its mission as

> to provide the technical knowledge required to support an informed decision in the early 1990's on whether or not to develop and deploy a defense of the U.S. and its Allies against ballistic missiles [Ref. 2: p. IV-1].

If a decision to develop and deploy a comprehensive defense against ballistic missiles were unable to be made until the early 1990s, it is likely that actual deployment would not begin until around the year 2000. Yet a technical panel from

---

[1] A complete glossary of acronyms is at Appendix A.

the George C. Marshall Institute in Washington, D.C. published its findings in January 1987 that

> technical progress in SDIO in the last two years has invalidated this traditional view. Several independent studies indicate that a space-based defense, attacking missiles in their boost phase, can be deployed in the the same time frame as the ground-based layers of the defense [Ref. 3: pp. 3-4]. (i.e., by 1994)

Furthermore, Secretary of Defense Caspar Weinberger indicated in May 1987 that

> no major technical roadblocks remain that would prevent initial U.S. deployment of a first-phase, layered, ballistic missile defense as early as 1993 . . . [Ref. 4].

This position is based in part on SDIO's own 1986 statement that

> in space-based kinetic energy weapons for boost-phase intercept, we have defined a concept for a simple chemical rocket based on low risk attainable technology at an affordable cost that would be effective in a near term defense [Ref. 2: p. II-11].

The possibility of an early decision on deployment prompts an examination of the effectiveness of such a system and how its deployment schedule might affect its effectiveness..

2. Technical

The trajectory of a ballistic missile, whether it is a land-based intercontinental ballistic missile (ICBM) or a submarine-launched ballistic missile (SLBM), consists of four phases: boost, post-boost, midcourse, and terminal. Boost phase includes the time from missile launch to the burn-out of the missile's booster stages above the atmosphere. During this time, the hot exhaust gases can easily be detected and tracked by infra-red (IR) sensors on surveillance and tracking satellites in high orbits. If the missile is equipped with multiple independently-targeted reentry vehicles, they are all carried on a post-boost vehicle (PBV) or "bus" on the missile throughout the boost phase. The post-boost phase begins after booster burnout, when the PBV maneuvers very precisely to place its reentry vehicles (RV) one by one in exact trajectories toward their targets. The IR signatures of the PBV's maneuvering jets are not as intense as when the missile was boosting in the atmosphere, but are nonetheless detectable against the cold background of space. As each RV is inserted into its trajectory by the PBV, it enters the midcourse phase of its flight. When all the PBV have dispensed all of their RV, the post-boost phase is over. The individual RV are now on ballistic paths to their targets and do no further maneuvering, thus giving off no appreciable IR

signature and becoming more difficult to locate. When the RV reenters the atmosphere, the terminal phase of its flight begins. The RV is constructed to protect the nuclear warhead inside it from the effects of atmospheric friction, and when the RV arrives at its target, the warhead detonates.

The U.S.S.R. has the only operational ballistic missile defense (BMD) system in the world today. It is designed to intercept RV in the terminal phase of their flights. The U.S. began to build such a system in the 1970s, but decided that a BMD that intercepted RV only in the terminal phase could be too easily overwhelmed by offensive proliferation, and so never deployed the system. Recent advances in technology, however, have made it potentially feasible to intercept RV throughout their flight, from launch to impact, thus reducing the load on a terminal defense. In particular, it may be possible to intercept and destroy ICBM and SLBM in the boost phase, when all the RV are still on board the booster or PBV, thus gaining enormous leverage over an attacking force. These interceptions may continue through the post-boost and midcourse phases as well.

The means for interception during the boost and post-boost phases could be satellites equipped with kinetic energy weapons such as rockets or electromagnetic rail guns, or with directed energy weapons such as lasers or particle beams. These same weapons could be used to accomplish the midcourse mission, along with very-high-altitude interceptor rockets launched from the ground. Such a layered defense, intercepting attacking ICBM and SLBM throughout the 2000 or so seconds of their flights, might reduce an attacker's confidence in suppressing retaliation. This might be sufficient to deter the initial attack.

One possible method of accomplishing boost-phase intercept might be with the Space-Based Kinetic Kill Vehicle (SBKKV). The SBKKV is similar to the Anti-Satellite missile developed for launch from the U.S. Air Force F-15 fighter plane [Ref. 5: p. 35]. An SBKKV would be a small one- or two-stage rocket with an IR seeker to home in on the exhaust gases of a boosting ICBM or a maneuvering PBV, and would destroy its target and all the RV on board by simple collision at high speed. Any number of SBKKV could be carried on a launcher satellite platform, though most public proposals consider from 5 to 25 SBKKV per platform. SBKKV would be alerted, targeted, and fired by battle management[2] satellites, and surveillance and tracking satellites would alert the battle management satellites.

---

[2]Battle management is the process of deciding which SBKKV should be launched against which targets.

There are many potential countermeasures to the various layers of a comprehensive BMD system. Some ways for an attacking force to avoid being intercepted by SBKKV include attacking the surveillance and battle management satellites, attacking the SBKKV platforms, and changing the flight characteristics of the ICBM and SLBM to make them less vulnerable to interception. Possible means to avoid interception during midcourse include the deployment of penetration aids from the PBV at the same time that it dispenses the RV. These penetration aids could include chaff and light and heavy decoys to overwhelm the midcourse tracking and battle management systems with many thousands of potential targets, only a few of which would actually be carrying nuclear warheads. To overwhelm terminal defenses, attacks could be coordinated so that many RV arrive over the target at once. Also, RV might be able to maneuver to escape ground-launched terminal interceptors.

The most frequently mentioned potential counter to the boost phase use of SBKKV is the so-called Fast-Burn Booster (FBB). This would be a ballistic missile designed and built to complete its boost phase in much less time than missiles currently in the world's arsenals. Such a booster would reach its full speed much sooner than a conventional booster, and so be able to send its payload of RV on the PBV at high speed through a SBKKV defense layer. This would reduce the time of vulnerability for the RV by enabling them to be deployed sooner from the maneuvering PBV with its tell-tale IR signature, thus avoiding IR sensors.[3] The FBB must not burn out at too low an altitude, though, else the PBV and deploying RV will be subject to atmospheric drag and lose accuracy [Ref. 7: p. 177].

An FBB would, however, have the disadvantage of the additional weight of materials required to strengthen it against the internal stresses resulting from higher acceleration and against the greater external forces of atmospheric resistance at higher speeds. This weight penalty would reduce its potential payload from the 10 RV currently carried by the world's largest ICBM to a maximum of perhaps 3 RV [Refs. 2,8: pp. VI-12, 17]. The weight penalty would also reduce the number of penetration aids that could be carried on board the PBV, thus reducing the midcourse discrimination problem for the defense. Another disadvantage of a FBB is that the

[3] It might be possible to overcome dependence on IR tracking by using homing radars on each KKV. However, to equip SBKKV with radar homing devices may not be practical due to the additional weight and power requirements, to the confusion which would result if many SBKKV were to be illuminating their targets at the same frequency simultaneously, and to the problem of strengthening the radar components to survive 20 g acceleration.

necessary sensor, feedback, and engine thrust controls are beyond current technology and would be very expensive and time-consuming to develop [Ref. 8: p. 15].

C. IMPLICATIONS

One of the problems facing U.S. development and deployment of a comprehensive BMD system is that the U.S.S.R. can begin to take countermeasures before the U.S. system is fully deployed. **The key to a capable and worthwhile U.S. defense system is to anticipate Soviet responses to ensure that the system will continue to be able to perform its mission in the future.** The potential for FBB to be one of those responses is real: "SDI officials believe the Soviets could develop fast-burn technology within seven years," [Ref. 9: p. 29] i.e., by 1994.

A Soviet FBB development date of 1994 coincides with the potential start of early deployment for a near-term U.S. defense if the decision were made in 1987 to proceed with full-scale development. However, an initial Soviet fast-burn capability developed by 1994 would not negate the value of a near-term U.S. boost and post-boost phase defense based on SBKKV. Just as the U.S. defense will take years to fully deploy, additions of significant numbers of FBB or conversion of the Soviet conventional missile force to FBB will also take years. In the interim, the vast bulk of Soviet ICBM and SLBM will continue to be of the older slower models, and this is a force against which the U.S. still will have to defend effectively.

This thesis develops a systems analysis approach to study the time-phased interaction of threats and defenses. In Chapter II, possible measures of effectiveness are examined to find one which is most appropriate for the boost phase subsystem of an overall defense system. In Chapter III, the results of simulations of static interactions are applied and a computer program is developed to model the dynamic process of defensive deployment and offensive penetration. In order to deal with the random failures of real-world equipment, the computer program incorporates the results of a probabilistic analysis of ICBM/PBV survival. Chapter IV presents the optimization of start date and deployment rates to achieve the desired level of effectiveness throughout the lifetime of the system. Analysis of the sensitivity of the results to the effectiveness of the individual KKV is also conducted. The sensitivity of SBKKV layer effectiveness to deployment delays, smoothed production/deployment schedules, and reliance on the Space Shuttle are also demonstrated.

The conclusions reached in Chapter V are generally applicable to various strategic defense systems and layers. **The methodology developed is independent of any**

particular threat forecast or engagement simulation model. Analysts will be able to apply this approach with different inputs to support long-range studies and decisions.

II. MEASURES OF EFFECTIVENESS

A. GENERAL

Before the effectiveness of a BMD system can be discussed, it is first necessary to address measures of effectiveness in general, measures of BMD system effectiveness, and the inputs to that effectiveness. An operational definition of an MOE is that it

> tells us how well we are doing in making decisions, and how well pleased we are with the outcomes resulting from our actions. This lets us rank the outcomes from alternative courses of action . . . ." [Ref. 10: p. 1]

Complex and expensive systems such as BMD particularly need valid MOEs in order to show when optimal (or even satisfactory) results have been achieved from the system by changing various inputs. The selection of an MOE is often complicated because

> (1) there are usually several possible MOEs, (2) it is useful to compare them in a given study, in particular to see if conclusions change when different MOEs are used, especially since (3) the choice between MOEs is sometimes only a subjective matter [Ref. 11].

B. BMD EFFECTIVENESS

In a strategic sense, the true MOE of a U.S. BMD is whether it helps deter nuclear war. Since it is impossible to measure the relationships of all possible inputs to deterrence, of which a BMD would be only one, the effectiveness of a U.S. BMD has been proposed to be measured in other ways. One author has suggested that BMD effectiveness be measured in terms of surviving U.S. ICBM retaliatory capability [Ref. 12: p. 64]. Often the proposed MOE is the percentage of attacking RV intercepted and destroyed by the defense, but percentages are meaningless without knowledge of the total number of RV that were launched. Efficiency, in terms of the cost-exchange ratio of RV killed per SBKKV in orbit, is another possible MOE, although we should remember that in many situations, "efficiency can be the mortal enemy of effectiveness [Ref. 13]." The SDIO has stated its MOE as follows:

> low leakage of nuclear warheads when threatened by large, sophisticated attacks as well as attacks on the defense system itself [Ref. 2: p. V-1].

That is an overall BMD system MOE, but the system will consist of several layers. Accordingly, "there exists a hierarchy of MOE's . . . ." [Ref. 10: p. 3]. The midcourse defense will be designed to receive those RV which leak through the SBKKV layer, so **the MOE for the SBKKV layer should be measured in terms of absolute numbers (not percentages) of RV acceptable to the midcourse layer.** Furthermore, the cost of a space-based defense layer and the changing nature of the threat over time dictate that this MOE be evaluated not by a snapshot of performance when final operational capability (FOC) is reached, but continuously from the beginning of SBKKV deployment.

The Marshall Institute studied a BMD system composed of three layers: SBKKV as the first layer, ground-launched high-altitude rocket interceptor KKV for the midcourse layer, and ground-launched low-altitude rocket interceptor KKV for terminal defense. When this system reached its FOC, there would be 11,000 SBKKV in orbit, and these SBKKV would be able to intercept 76% of 11,200 RV launched in an all-out attack [Ref. 3: p. 40]. This amounts to an absolute number of 2688 RV penetrating the SBKKV layer and entering the midcourse phase of their flights. Given the stature of the Marshall Institute study, it was felt that 2688 would be a valid objective for the maximum number of RV allowed to penetrate the SBKKV layer in the present study.[4] Accordingly, **the present study looks at the performance of a boost and post-boost defense layer (consisting of SBKKV on satellite platforms) with a maximum leakage of 2688 RV challenged by an evolving Soviet threat over the years 1994 to 2004 inclusive.**

C. INPUTS TO THE MOE

Penetration of the defense layer by attacking RV happens as the result of engagements. An engagement is characterized by the date the attack occurs, the threat at that time, and the number of SBKKV in orbit. Other primary, secondary, and tertiary inputs are as follows (the f, g's, and h's denote functional relationships):

---

[4]Actually, the maximum number allowable through the first layer depends on the capabilities of the second and third layers to reduce that leakage to some (presumably much smaller) final level, and those capabilities may change over time. Whatever level of effectiveness is finally required of the space-based layer, the methodology developed here still can be applied.

MOE value = f(current and previous SBKKV deployment rates, SBKKV deployment start date, space-based defense layer system reliability, year of engagement, desired level of confidence in the layer's performance, surface in SBKKV x YEAR x RV-targeted space)

- deployment rates = g1(space launch capacity, SBKKV platform size and weight, platform production, budget and political considerations)
- start date = g2(technical progress, mass production capability, budget and political considerations)
- system reliability = g3(probability that a KKV will hit its target (p(k)), reliability of all other components)
- year of engagement = g4(political considerations)
- surface = g5(threat, defensive system, launch time of day)
    - threat = h1(ICBM and SLBM booster types, number of RV per booster type, booster burnout times by type, individual RV deployment times from PBV, number of attacking boosters of different types, locations of ICBM launch fields by type, number of ICBM in each launch field, targets and trajectories, booster technology and production development rate, BMD suppression capability)
    - defensive system = h2(number of orbital rings, number of platforms per ring, number of KKV per platform, KKV acceleration, KKV final velocity, angle of orbital inclination, phasing fraction (or phasing angle), platform altitude, system reaction time, system survivability)
    - launch time of day = h3(time of least defensive coverage, military considerations, political considerations)

Some of the above-listed factors are unknown and unknowable, e.g. future political and budgetary considerations. The rest can be set as either fixed parameters, parameters to be varied to examine their effects on the MOE, or decision variables. The decision variables are under the control of decisionmakers and can be varied in order to optimize the measure of effectiveness relative to the parameters. For this study, the yearly deployment rates are the decision variables. The parameters varied to produce different conditions are the KKV p(k) and the desired confidence level. The values assumed for all other parameters are discussed in Chapters III and IV.

III. MODELING EFFORT

A. INITIAL INSIGHTS

The modeling effort began with the initial insight that the number of RV that would penetrate a boost and post-boost phase defense depended on the number and type of RV that were launched and the number of SBKKV available (all other factors held constant). In particular, for a specific threat mix of RV on various boosters, a convex curve would probably best describe the relationship between the (independent) number of SBKKV deployed and the (dependent) number of RV penetrating. This curve would start at some maximum when no SBKKV were deployed (and all RV launched would penetrate), decline as SBKKV were added, and finally exhibit diminishing marginal returns as the number of SBKKV became quite large (see Figure 3.1).

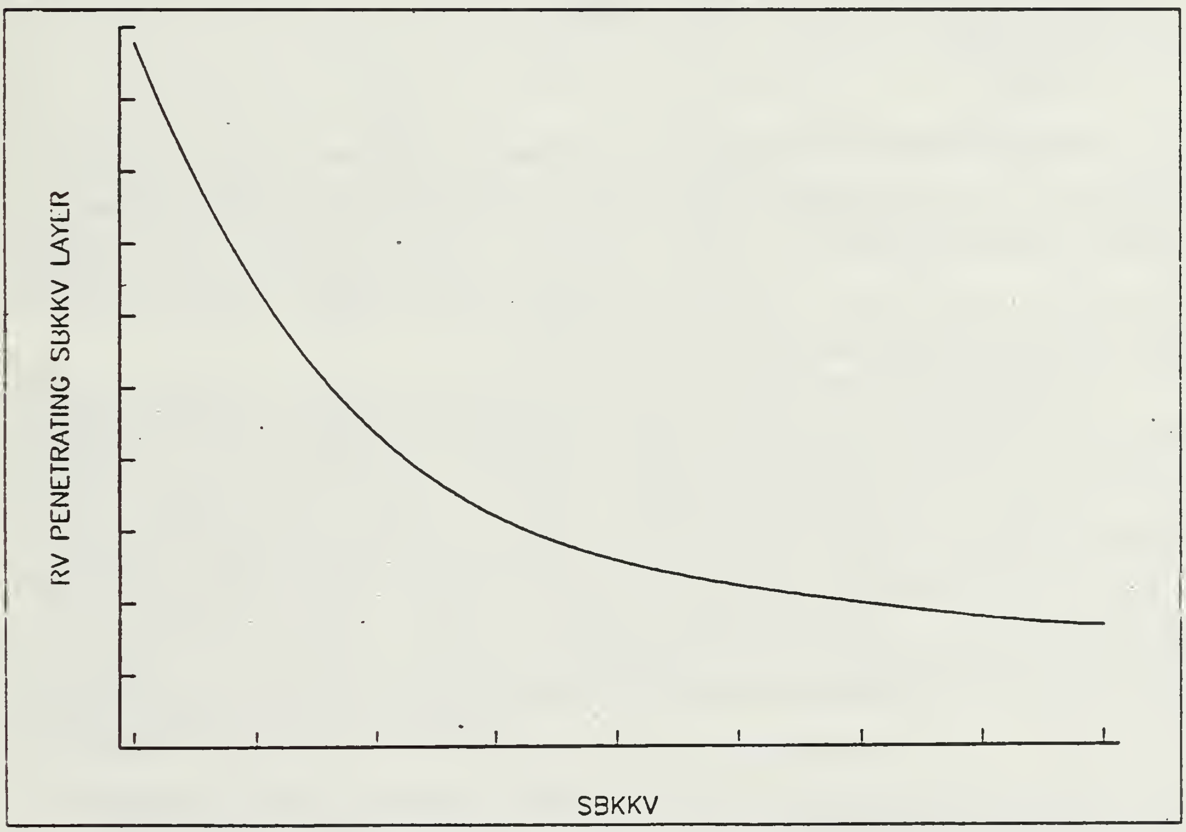

Figure 3.1 POSTULATED RV PENETRATION CURVE.

Furthermore, this sort of curve would describe the relationship between SBKKV deployed and RV penetrating for any threat, with variations in maximum due to total number of RV launched, and changes in curvature due to the mix of booster types as the threat changed over time. Thus, each year from 1994 to 2004 could be described by a particular curve in the SBKKV x RV plane, and if an orthogonal axis were to describe the year of the engagement, a **surface would result directly relating the number of SBKKV deployed and the year of the engagement to the number of RV penetrating the SBKKV layer.**

The number of SBKKV available to participate in the defense in any particular year would be a function of the year the SBKKV were first deployed and the annual rate of further deployments. Thus, given a surface which would reflect assumptions about the change in the threat over time and the performance of SBKKV against such threats, **it would be possible to directly relate decisions about deployment start date and deployment rate to the MOE, number of RV penetrating the SBKKV layer.** This concept is graphically demonstrated in Appendix E.

B. GENERATING THE TARGETING SURFACE

1. Assumptions

a. Threat

From the previous discussion, it is clear that different assumptions about the magnitude of the attacking force and its mix of booster types over time will result in different surfaces in SBKKV x YEAR x RV space. For the purposes of this study, only one surface was needed in order to demonstrate the approach, and so only one Soviet development and launch scenario was prepared.

Although SBKKV would be effective against both ICBM and SLBM in the boost and post-boost phases of their flights, SLBM were not considered in this study due to the lack of available information about their flight characteristics, the imprecision of their launching areas, and the likelihood that the initial effort to develop FBB would be for land-based missiles. It should be noted that the SBKKV in the vicinity of the Soviet land mass defending against ICBM would not be facing a significant number of SLBM and that SLBM and their PBV would be engaged by SBKKV located over other parts of the globe, so the results of this study are robust in the face of this decision. Larger, more comprehensive modeling efforts with access to accurate data about SLBM would certainly need to include them.

The issue of system survivability against direct attack was considered an unnecessary complication of the basic effort of this study. Relative to system survivability then, the results of this study will be optimistic. The assumption of perfect survival would have to be investigated before any future study based on the methodology presented here could be considered valid for production/deployment decisions.

It was further decided not to model all-out first strikes[5] with every ICBM in the projected Soviet inventories. Of the ICBM in the forecast inventories, only two-thirds of each type would be used in the model engagements, except that all of the FBB would be used. The reasons for this assumption were:

- It is not likely that the Soviets would leave themselves without some sort of ICBM capability for use against other nuclear powers in the event of general nuclear war, particularly if the SS-20 and similar longer range intermediate-range missiles are reduced or eliminated.
- Soviet military science, while stressing the importance of overwhelming initial nuclear strikes, also stresses the need for readily and continuously available reserve forces.
- It is not likely that the Strategic Rocket Forces would have a force size so small that they would be required to cede the nuclear strike role entirely to the Navy and Long Range Aviation for the duration of a war.
- The sole purpose of the FBB would be to penetrate the SBKKV layer in the initial strike, so none of them would be held in reserve.

This assumption does not affect the validity of the methodology, did reduce the number of SBKKV needed, and did simplify the model.

It was further assumed that, if a U.S. decision to develop a BMD were made, the Soviets would find it in their best interests to allow treaty limitations on the numbers of nuclear warheads and strategic launchers to lapse. Furthermore, it was assumed that any new missiles developed would be mobile, so would not need the SS-18 and SS-19 silos, and so SS-18 and SS-19 ICBM would not be retired as new missiles entered the Soviet inventory. The other missiles in the scenario for this study were the SS-24, the SS-25, the SS-18 follow-on (FO) [Ref. 14: p. 31], and a notional FBB. Future production rates were assumed by using approximate annual missile production for the years 1978-1986.[6]

---

[5]Soviet military doctrine states that the U.S.S.R. will not be an aggressor, but a preemptive strike is not ruled out if they believe an attack on them is imminent.

[6]Total Soviet ICBM production for that period was 1525, which averages to 170 per year [Refs. 14,15,16: pp. 122, 98, 79].

RV loads were assumed as follows: SS-18 - 10, SS-19 - 6, SS-24 - 10, SS-25 - 1, SS-18FO - 10, FBB - 3. Booster burnout times were assumed to range from almost 300 seconds for the oldest missiles down to 50 seconds for the FBB. Where information about particular Soviet missiles was unavailable, approximations based on the characteristics of similar U.S. missiles were used. PBV deployment times for each RV were assumed to range from about 50 seconds for the oldest missiles down to 30 seconds for the FBB [Refs. 6,17: pp. 22,25]. Geographic coordinates for thirteen launch sites were selected based on the maps in *Soviet Military Power* and an atlas of the Soviet Union [Ref. 14: p. 25]. The implication is that, given the locations of fixed silo fields and known mobile ICBM launching areas, battle management satellites will know which boosters are carrying the most warheads and be able to properly assign KKV against the most dangerous boosters.

In order to gain the most information from available computing resources, threat mixtures were modeled for the years 1994, 1995, 1999, and 2004. A complete table of the threats modeled is at Appendix B.

b. SBKKV Layer

The SBKKV were assumed to be deployed 10 to a platform at an altitude of 557 kilometers in orbital rings of 20 platforms per ring inclined at 85 degrees from the equator. The SBKKV were assumed to have a 20 g acceleration rate, and a final velocity of 6 km/sec [Ref. 3: p. 20], which implied about 31 seconds of acceleration. The salvo size was chosen to be one KKV per target, rather than two. Shoot-look-shoot targeting was deemed impractical for a system facing so many targets moving so fast, and firing a salvo of two KKV per target with a high probability of kill (p(k)) for each KKV would have been wasteful of assets. The time required after ICBM launch for target acquisition, tracking, battle management, and communications was assumed to be 50 seconds. All KKV were then launched at once. Even though SBKKV may have some capability against RV in midcourse, it was decided to limit the modeling to the boost and post-boost phases only, due to the entirely different targeting problems faced in midcourse as a result of decoys and chaff.[7]

---

[7] In the event, the model data indicated that all RV kills occurred in boost phase.

2. RAND Model

a. General

Having determined the engagement scenarios to be modeled, an engagement simulation developed in 1983 at the RAND Corporation by H. Hoover and M. Miller was used to generate the actual targeting surface in SBKKV x YEAR x RV space. It is a deterministic model, with no random inputs at all. Knowing which boosters are launched from which locations at which time, it tracks the spatial relationships between all the platforms of a SBKKV constellation and all the ICBM and PBV, in time-steps of 10 seconds. Having recorded all occasions when an interception could have been made during this time, it then uses an application of the transportation problem of linear programming to assign SBKKV on a one-for-one basis[8] to prioritized targets (ICBM or PBV) which are within range. The objective of these assignments is to use all KKV which will be in range of targets to maximize the number of RV (not just boosters) which would have been destroyed if the system worked perfectly, subject to the limits on available KKV.[9] The number of RV targeted in the engagement is the output of the model.

By reporting the number of RV which could be destroyed, the simulation in effect assumes perfect reliability of all defense subsystems from surveillance through acquisition, tracking, battle management, communications, and KKV. This characteristic of the model can be exploited to allow various p(k) to be applied to the results later, in order to glean more information from its output about the effectiveness of a space-based defense layer. This will be discussed further in Section III-C (Complete Model).

In order to gain the most information about the shape of the postulated curves in the RV x SBKKV plane, the numbers of platforms modeled were: 100, 200, 300, 500, 700, 1000, 1300, 1500, and 2000. These choices emphasized the parts of the curves believed to be most sensitive to variations in the number of platforms.

---

[8]Recall that KKV salvo size was set at one.

[9]For a given SBKKV, this procedure would, for example, prefer a partially-empty SS-18 PBV with 8 RV still on board to a still-boosting SS-19 with all 6 RV on board. However, this procedure would not preclude a KKV from being targeted at a 1-RV SS-25, if all other ICBM within range of that KKV had already been targeted by other KKV.

b. Inputs

The 4 different threat year-mixes (shown in Appendix B) and 9 SBKKV platform levels provided for 36 output values on the targeting surface in SBKKV x YEAR x RV space. Further inputs for all the runs for this particular study were:

- each platform carried 10 KKV
- KKV acceleration of 20 g (196 m/sec^2)
- KKV final velocity of 6 km/sec
- salvo size of 1 KKV per target
- platform altitude of 557 km [Ref. 18]
- 20 equally-spaced platforms per orbital ring
- number of rings in the constellation (in this study, the number of rings for any given run equalled the number of platforms ÷ 20)
- 85 degree inclination of the orbits relative to the equator [Ref. 18]
- zero phasing fraction (i.e., when one ring had a satellite over the equator, all rings did) [Ref. 18]
- 50 second delay from ICBM launch to KKV launch
- geographic coordinates for the 13 ICBM launch fields
- RV target areas in the center of the U.S. (this was sufficiently accurate for this study, which did not track the RV into the midcourse phase) [Ref. 18]
- near-minimum energy trajectories [Ref. 18]
- burnout times for the different types of boosters
- RV deployment times for the different types of boosters
- initial number of RV launched on each type of PBV
- for this study, all ICBM were launched simultaneously on each run, and the launch occurred for each run when one of the SBKKV platforms was over 0 degrees latitude, 0 degrees longitude, thus maintaining consistency among all runs [Ref. 18].

Dr. Miller used his model and the above inputs to provide the 36 raw data points needed to generate the targeting surface in SBKKV x YEAR x RV space.

c. Outputs

Each run produced the number of RV targeted for destruction before entering midcourse.[10] The results of each run are shown in Table 1. Since all types of

[10]It should be noted that these results are sensitive to different ICBM launch times relative to the location of an "index platform," and coverage could be less or more complete at different times (i.e., when the index platform is not at 0 - 0 when the ICBM are launched). This variation, however, is reduced as more and more platforms are deployed. The time for one of these constellations to repeat itself when 100

conventional ICBM (but no FBB) were launched in 1994, and since a sufficiently dense constellation of platforms (2000) was able to target all of them, it is concluded that the KKV are capable of intercepting all PBV either while still on their boosters or before dispensing any of their RV. It is also concluded that, since the scenario added only FBB to the Soviet inventory after 1999, and yet the number of RV targeted in 2004 is the same as in 1999 for any number of SBKKV platforms, that the RV from FBB were always deployed before the first KKV could have arrived.

TABLE 1

RAW DATA ON RV TARGETED (FROM RAND MODEL)

PLATFORMS	YEARS			
	1994	1995	1999	2004
100	1340	1340	1440	1440
200	2330	2340	2610	2610
300	3040	3130	3690	3690
500	3700	3990	5490	5490
700	4010	4370	6340	6340
1000	4260	4750	7050	7050
1300	4340	4900	7510	7510
1500	4350	4950	7760	7760
2000	4360	5020	8030	8030

Plots of the RV not targeted, which are the difference between RVLNCH and RVTGT, are shown by year in Figure 3.2. These plots confirm the initial insight of Chapter III.

3. Fitting the Surface

A targeted RV surface of 220 points in SBKKV x YEAR x RV space for the years 1994-2004, and for SBKKV platform deployments in integral multiples of 100 from 100 to 2000 was derived using GRAFSTAT.[11] Initial investigation of the 36 raw data points revealed that, when plotted in the SBKKV x RV plane, a 6th degree polynomial provided the best fit to the data between 100 and 1500 platforms and that

---

platforms (5 rings) are in orbit is 288 minutes, and when 2000 (100 rings) are in orbit it is only 14 minutes [Ref. 18].

[11] "GRAFSTAT is an interactive data analysis and plotting tool" which is "written in APL." [Ref. 19: pp. iii, 1]

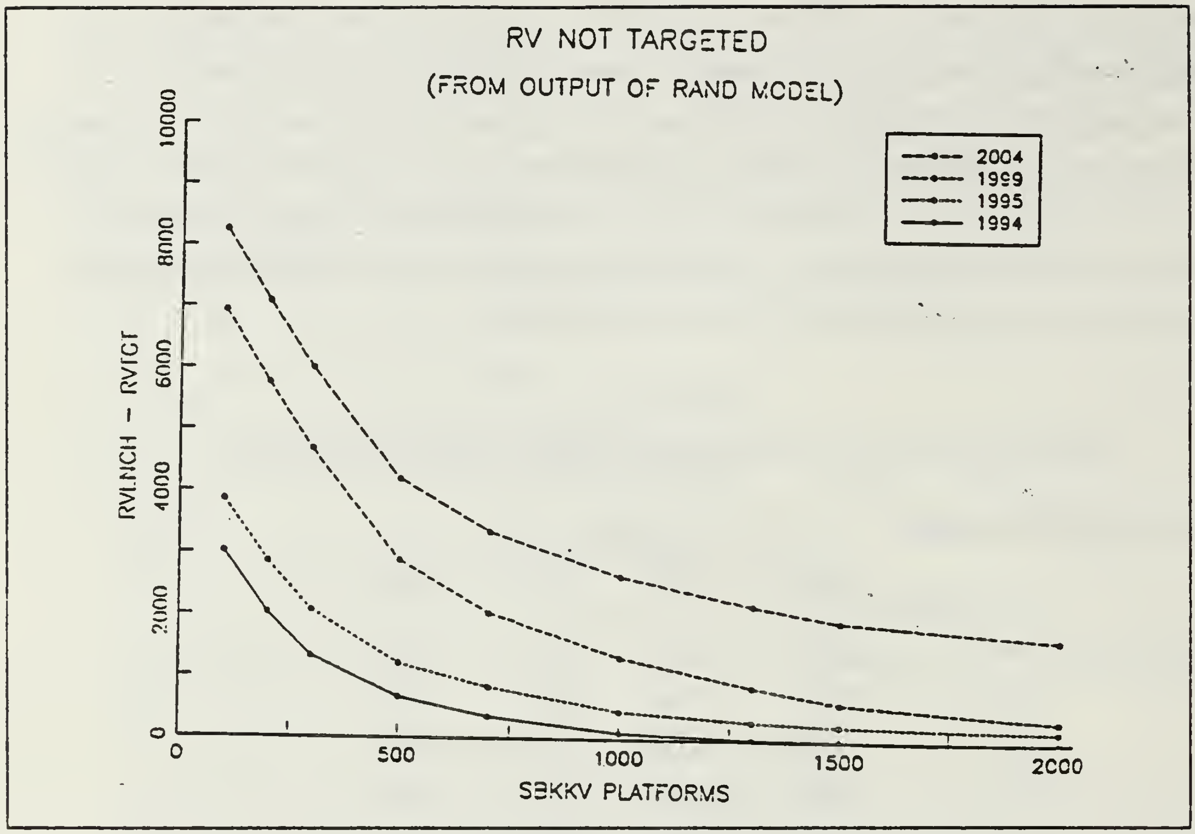

Figure 3.2 RV PENETRATING BECAUSE NOT TARGETED.

straight lines would be satisfactory between 0 and 100 platforms[12] and between 1500 and 2000 platforms. Also, when plotted in the YEAR x RV plane, the data were best described by a 2d degree polynomial from 1994 to 1999, and parallel lines from 1999 to 2004 (reflecting the inability to target the FBB). See Figure 3.3.

Two converging approaches were used to obtain the RV values for the 184 SBKKV x YEAR intersections not explicitly given by the model output:

- interpolate the three[13] 9 x 4 constant-year plots to obtain three 20 x 4 data plots in the SBKKV x RV plane, and then transform them into 4 x 20 constant-platform plots in the YEAR x RV plane to obtain the six complete 11 x 20 data points in Figure 3.4.
- interpolate the nine 4 x 9 constant-platform plots in the YEAR x RV plane to obtain nine 11 x 9 data plots and transform them into eleven 9 x 11 constant-year plots in the SBKKV x RV plane to obtain the complete 20 x 11 data points in Figure 3.4.

---

[12]Results for less than 100 platforms (5 rings) are not significant anyway due to lack of coverage.

[13]Remember that the data for 2004 duplicated 1999.

The results were almost identical (no differences greater than 3 RV), so they were averaged to obtain the data presented in Table 2. The surface appears in a three-dimensional plot in Figure 3.5. The points were entered into the data file TARGET for reference by the program developed in Subsection III-C-3, Programming.

C. COMPLETE MODEL

1. Binomial Distribution of Interceptions

The SBKKV x YEAR x RV targeting surface was generated from data which considered all possibilities for RV interception[14] and implied a total defense system reliability and KKV p(k) of 1.0. A realistic view of the situation being modeled requires the application of a p(k) less than 1.0 to determine the actual number of RV penetrating the SBKKV layer (RVPEN). That is,

$$\text{RVPEN} \neq \text{RVLNCH} - \text{RVTGT},$$

because

$$\text{RVTGT} = \text{RVHIT} + \text{RVMISSED},$$

where RVTGT (the RAND model output) is limited by the number of KKV available and within range.[15] Thus,

$$\text{RVPEN} = (\text{RVLNCH} - \text{RVTGT}) + (\text{RVTGT} - \text{RVHIT}).$$

The data give the value of RVTGT outright as a result of the mechanics of the input parameters, thus explicitly determining the value of RVLNCH − RVTGT. It is the value of RVHIT which is subject to random effects. At first glance, it might appear that the value of RVHIT could be considered a straightforward Binomial random variable with parameters RVTGT and some overall probability of RV destruction as the parameters. This, however, is **not the case,** because the Binomial distribution requires independence of individual events, and RV are not destroyed independently. KKV destroy RV in groups of 10 or 6 or however many are on the booster when it is intercepted.

---

[14]Note that whether or not an RV can be targeted is determined solely by the mechanics of the boosters, orbits, and SBKKV once the ICBM are launched. The launch time will presumably be chosen by an attacker to minimize the number of possible interceptions by launching when gaps or minimum coverage occur based on knowledge of the platform orbits and his own ICBM trajectories.

[15]There will almost always be more conventional boosters launched than KKV close enough to target them.

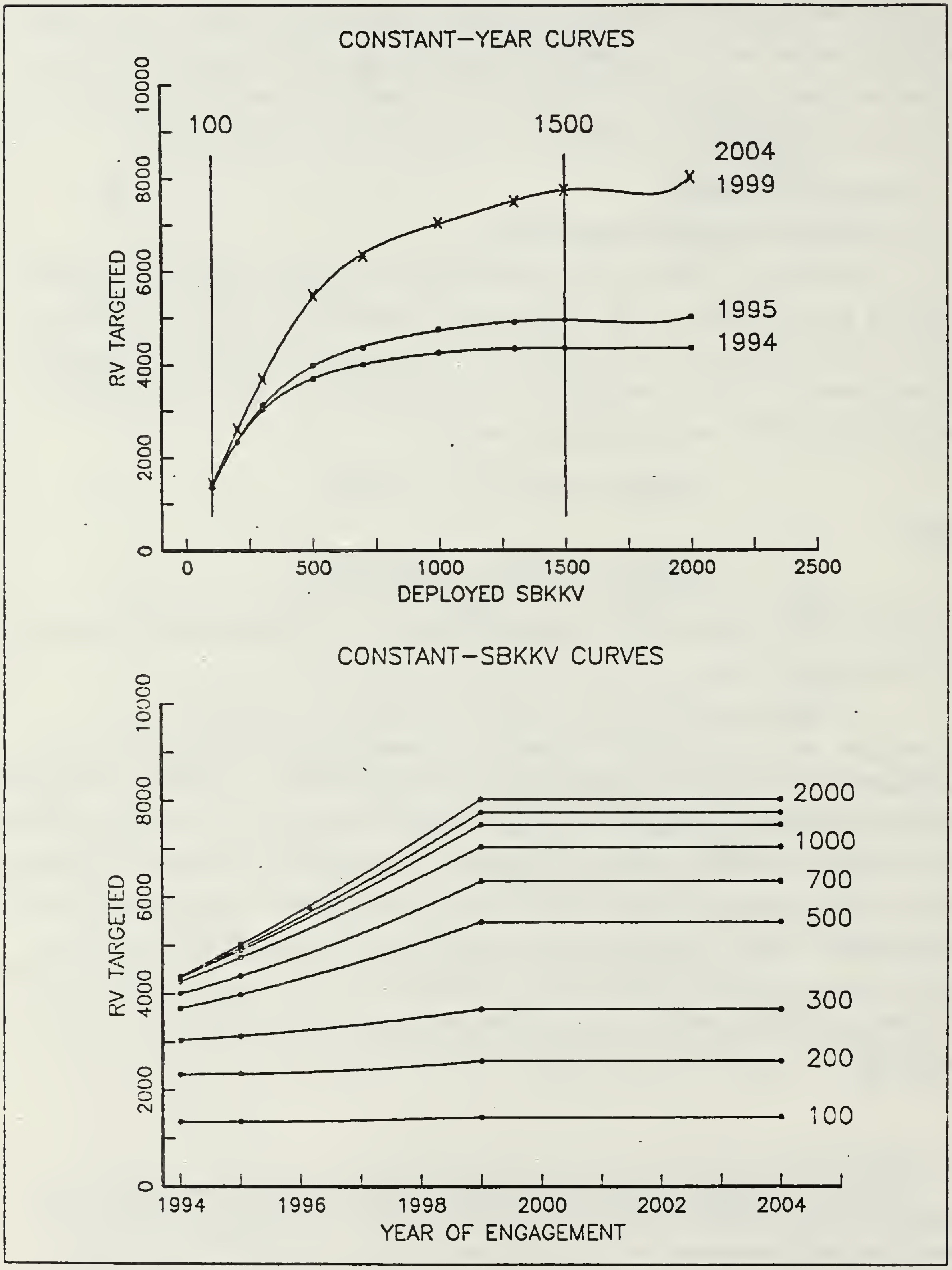

Figure 3.3 FITTING THE RAW TARGETING DATA.

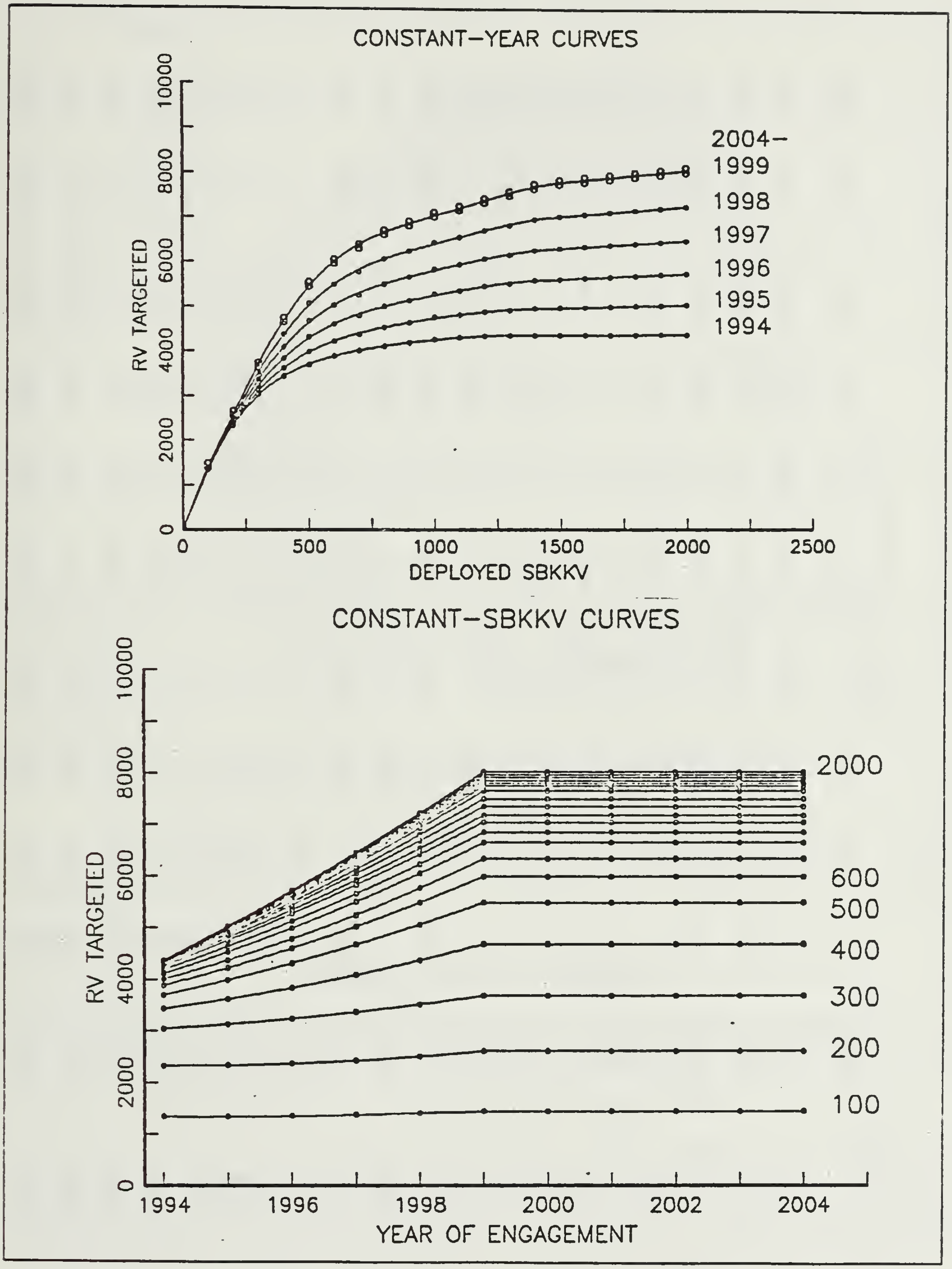

Figure 3.4 THE INTERPOLATED TARGETING DATA.

TABLE 2

INTERPOLATED RESULTS FOR ALL ENGAGEMENTS: TARGETED RV

PLATFORMS	YEAR OF ENGAGEMENT										
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
100	1340	1340	1350	1370	1400	1440	1440	1440	1440	1440	1440
200	2330	2340	2373	2429	2508	2610	2610	2610	2610	2610	2610
300	3040	3130	3240	3370	3520	3690	3690	3690	3690	3690	3690
400	3435	3622	3840	4090	4372	4684	4684	4684	4684	4684	4684
500	3700	3990	4314	4672	5064	5490	5490	5490	5490	5490	5490
600	3887	4223	4602	5024	5490	5998	5998	5998	5998	5998	5998
700	4010	4370	4783	5249	5768	6340	6340	6340	6340	6340	6340
800	4113	4530	4993	5501	6055	6654	6654	6654	6654	6654	6654
900	4191	4637	5126	5659	6234	6853	6853	6853	6853	6853	6853
1000	4260	4750	5274	5832	6424	7050	7050	7050	7050	7050	7050
1100	4299	4805	5347	5925	6539	7189	7189	7189	7189	7189	7189
1200	4329	4868	5441	6047	6687	7360	7360	7360	7360	7360	7360
1300	4340	4900	5497	6131	6802	7510	7510	7510	7510	7510	7510
1400	4345	4941	5570	6233	6932	7665	7665	7665	7665	7665	7665
1500	4350	4950	5591	6273	6996	7760	7760	7760	7760	7760	7760
1600	4352	4964	5616	6309	7041	7814	7814	7814	7814	7814	7814
1700	4354	4978	5641	6344	7086	7868	7868	7868	7868	7868	7868
1800	4356	4992	5667	6380	7132	7922	7922	7922	7922	7922	7922
1900	4358	5006	5692	6415	7177	7976	7976	7976	7976	7976	7976
2000	4360	5020	5717	6451	7222	8030	8030	8030	8030	8030	8030

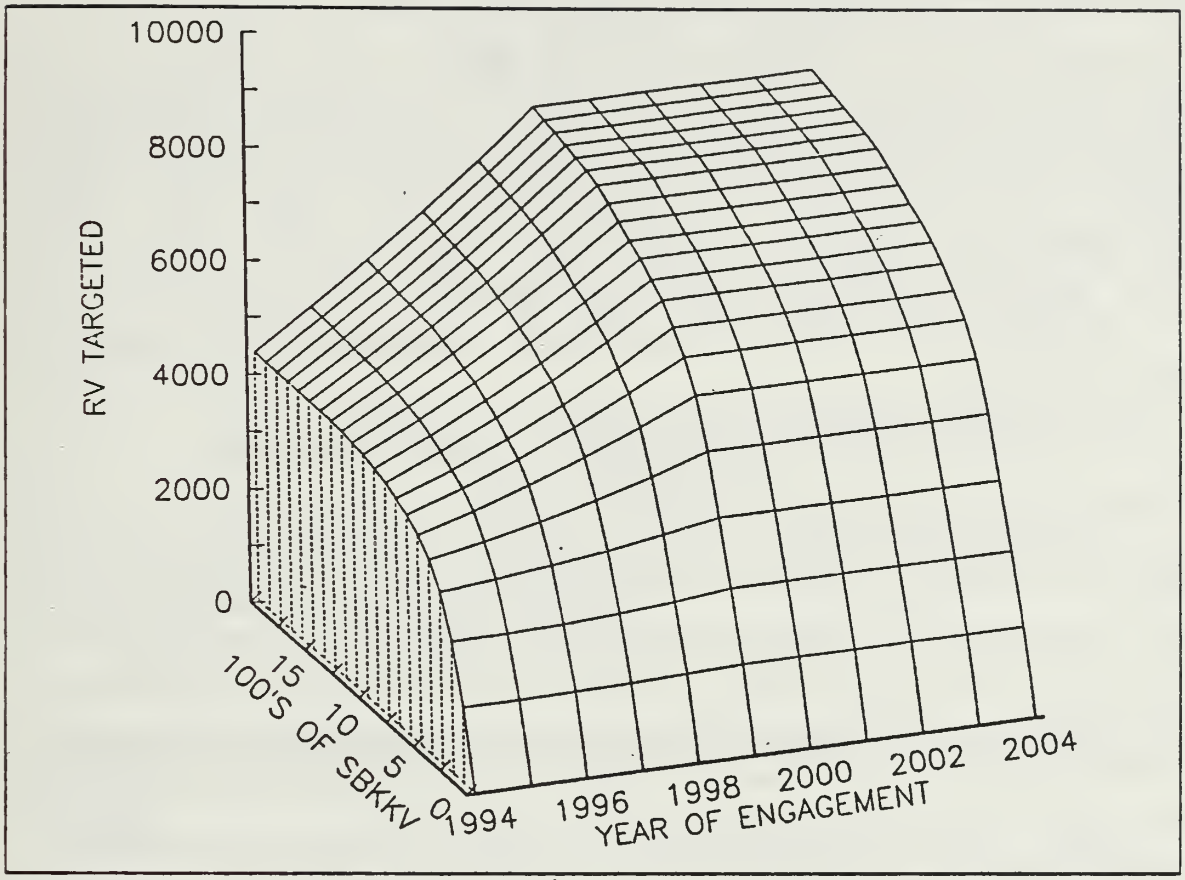

Figure 3.5 THE TARGETED RV SURFACE.

KKV intercept of a booster results in RV destruction, so the total number of RV destroyed depends on the number and type (SS-18, SS-19, SS-24, SS-25, SS-18FO)[16] of boosters intercepted and the number of RV carried on each intercepted booster. That is,

$$RVHIT = \Sigma\,(RV_i) \times (BHIT_i),$$

where i indicates booster type and the $BHIT_i$ are random variables. Recalling that an earlier assumption was that only one KKV would be fired at each targeted booster, the number of boosters intercepted of each type thus depends directly on the number of KKV fired at boosters of each type and the p(k) of a KKV against each different type of booster. At this point, we have independent Bernoulli trials: either a KKV hits a targeted booster or it does not, independently of other KKV.[17] Thus, for each type of

[16]Recall that the KKV were unable to target any of the FBB.

[17]This assumption is not entirely conservative, because an entire platform of 10 KKV could fail or be destroyed (thus losing independence among the KKV), and the reliability of the surveillance, tracking, and battle management satellites is also assumed

booster, the number intercepted is a Binomial random variable:

$$BHIT_i \sim Bin(BTGT_i, p(k)_i),$$

where i refers to booster type. At this point, RVHIT is a function of five random variables with ten parameters, and further simplifying assumptions are needed. We will regroup the boosters from their five types into three categories: those carrying 10 RV (SS-18, SS-24, SS-18FO), those carrying 6 RV (SS-19), and those carrying 1 RV (SS-25),[18] and assume that the KKV p(k) is the same for all booster types.

RVHIT is now a function of three Binomial random variables, with only four different parameters:

$$RVHIT = (10)(Bin(BTGT_{10}, p(k))) + (6)(Bin(BTGT_6, p(k))) + (1)(Bin(BTGT_1, p(k))).$$

To determine the values of $BTGT_{10}$, $BTGT_6$, and $BTGT_1$, we proceed as follows: The number and category of boosters targeted during each engagement are derived from the SBKKV x YEAR x RV data and knowledge of the scenario and the characteristics of the RAND model. As noted earlier, RVLNCH and RVTGT are explicitly determined by the input launch scenario and the interpolated RV targeting data. The difference is the number of RV which were not targeted and thus made a "clean escape." It was earlier noted that all RV from FBB penetrated the SBKKV layer. Since the raw data indicated that all the conventional boosters were potentially vulnerable, those RV which are not targeted and thus make a clean escape (other than FBB RV) will be those from boosters with the least targeting priority. The least priority boosters are the SS-25s, with only one RV on board, followed by the SS-19s, with six RV on board. The top priority boosters are the 10-RV SS-18s, SS-24s, and SS-18FOs. Thus, the number and mix of targeted boosters can be determined by iteratively subtracting the low-priority RV launched in the scenario from the total number of RV which escaped, and comparing the result with the known numbers and mix of launchers in the attack. It will be recalled from previous data that the boosters targeted will be carrying full loads of 10, 6, or 1 RV when they are intercepted.

---

to be perfect. This assumption does, however, result in a lower bound on the number of SBKKV required for this scenario and MOE-level. More detailed modeling would have to be done in order to describe more precisely the effects and likelihood of imperfect support system operation or platform failure.

[18]This simplification is valid because the raw data indicated that all conventional boosters were vulnerable, because the model puts a priority on the 10-warhead boosters, and because the KKV p(k) is assumed to be the same for all boosters.

The random variable $RVHIT_i$ does not retain the Binomial probability law when the Binomial random variable $BHIT_i$ is transformed by scalar multiplication. Multiplication by the constant RV_i transforms the elements but not the size of the sample space over which $BHIT_i$ is defined. Furthermore, while the random variable $RVHIT_i$ has mean $(RV_i)(BTGT_i)(p(k))$, its variance is not $(RV_i)(BTGT_i)(p(k)(1 - p(k))$, which would indicate a Binomial distribution, but $(RV_i)^2 (BTGT_i)(p(k))(1 - p(k))$. We turn to the Normal approximation of the Binomial random variable $BHIT_i$:

$$BHIT_i \sim Bin(BTGT_i, p(k)) \rightarrow \sim N((BTGT_i)(p(k)), (BTGT_i)(p(k))(1 - p(k)))$$

The Normal approximation to the Binomial distribution is valid here due to the large numbers of boosters targeted after the first few platforms (carrying 10 KKV apiece) have been deployed.[19] The Normal distribution has the useful property of reproducing itself under linear transformations. Therefore,

$$RVHIT_i \sim N((RV_i)(BTGT_i)(p(k)), (RV_i)^2 (BTGT_i)(p(k))(1 - p(k))),$$

and

$$RVHIT \sim N(\Sigma (RV_i)(BTGT_i)(p(k)), \Sigma (RV_i)^2 (BTGT_i)(p(k))(1 - p(k))),$$

with mean

$$E(RVHIT) = (10)(BTGT_{10})(p(k)) + (6)(BTGT_6)(p(k)) + (BTGT_1)(p(k)),$$

and variance

$$VAR(RVHIT) = (100)(BTGT_{10})(p(k))(1 - p(k)) + (36)(BTGT_6)(p(k))(1 - p(k)) + (BTGT_1)(p(k))(1 - p(k)).$$

Note that for each engagement, the parameters of RVHIT will be different.

2. Confidence Interval

a. Defender's View

A BMD system is a critical system which must meet or exceed its design standards the one time it is needed.[20] Since RVPEN = RVLNCH − RVHIT, and RVHIT is well approximated by the Normal distribution, the expected value of RVPEN is also its median. A defender might wish to set a security goal positively

---

[19]It can be argued that there will be occasions when very few six- or one-RV boosters will be deployed, and that the Normal approximation is not valid for the distribution of BHIT for those categories on those occasions. However, those occurrences happen when all 10-RV boosters, or all 10-RV and 6-RV boosters, have already been targeted. In the aggregate, the approximation is still good.

[20]The present study does not address the situation of a conflict extended in time, with its consequent changes in attacking force mix and size and defending SBKKV platforms still functioning and with KKV on board.

under his control. To set the required level of effectiveness at the expected value of RVPEN would be to use the 50th percentile of the distribution; this would be very risky for a one-time system, as there would be a 50% chance that the required level of effectiveness would not be achieved. To be more certain of achieving his security goal, the defender would need to deploy SBKKV in sufficient numbers that a greater-than-50% upper one-sided confidence interval for the number of RV which penetrate the SBKKV layer can be achieved.This will be a level above the mean of RVPEN which is not likely to be exceeded. For any required confidence level, the number of SBKKV on station can be adjusted to achieve any desired RVPEN value, as determined by the Normal distribution of RVPEN.

b. Attacker's View

The attacker's view of such a random outcome is different. One goal in launching a first strike would be to prevent retaliation. The attacker would want a high degree of confidence that the defender's retaliatory capability will be suppressed. Thus, for a given engagement, he will set a threshold for RVPEN well below the mean in order to increase the chance that enough RV will penetrate the boost-phase defense layer to accomplish suppression and any other objectives of the attack. His threshold will be the limit of a lower one-sided confidence interval for RVPEN. The risk he is willing to accept will be α that RVPEN will not exceed this amount. A defender might wish to deploy merely enough SBKKV on station that the attacker will be unable to achieve this goal with his desired degree of confidence, so that the attacker will be deterred.[21] Fewer SBKKV are required for this mission, however the price paid is that the defender no longer is positively controlling his own security, but is trying to manage the perceptions of his potential opponent. Additionally, if an attacker were to acquire a BMD capability, his confidence in a successful attack at a lower threshold of RVPEN would increase, as his BMD system would negate most or all of any retaliatory strike. The defender would be forced to react to this new lower threshold and quickly deploy more SBKKV in order to again reduce the attacker's confidence in success.

[21]The defender's decision on the number of SBKKV needed to deter depends, of course, on knowledge or assumptions about the attacker's success threshold, the attacker's desired degree of confidence in achieving that threshold, and the attacker's opinion of the capabilities of the defense layer.

3. Programming

Once the SBKKV x YEAR x RV targeting surface was established through simulation and interpolation, it remained to write a program to relate SBKKV deployment rates to RV penetrating the SBKKV defense layer in any year 1994-2004. VS FORTRAN was chosen as the language for this program, due to its universality and transportability, should others wish to apply it with their own inputs.

The program begins with a DATA statement so the user can set his desired value for the KKV's p(k), for the value of Z needed to achieve the desired confidence interval, and the deployment start date to be used. The program then reads the entire targeting surface data file (TARGET) and a short file (LAUNCH) which contains the (potential) number of attacking RV at the end of each year 1993-2004. It then reads an input file with the user-determined platform deployment rates per month for the years 1994-2004 and computes and stores the number of SBKKV platforms deployed for each month from January 1994 to December 2004.

Then for each engagement, month by month until January 2005 or a platform value greater than 2000 is reached, the following sequence of computations is performed:

- the number of RV and boosters launched is computed by category (10, 6, 3, or 1 RV per booster)
- the total number of RV targeted is obtained by four-point linear interpolation [Ref. 20: p. 882] from the data file 'TARGET' which is given in Appendix C
- the iterative subtraction process described previously is applied to determine the number of targeted boosters in categories 10, 6, and 1
- the expected value and variance of RVHIT are computed
- the expected value of RVPEN is calculated
- the appropriate value of Z is applied in order to determine the limit of the desired confidence interval for RVPEN.

Further details are elaborated in the program documentation in Appendix C.

The output shows, for each month, the number of platforms deployed, the number of RV launched, the average number of RV that penetrate the layer, the number of RV that penetrate with the required confidence level, and the year of the engagement. The output produced for a system deployed starting in January 1994, with KKV p(k) = .9 and security goal confidence level 99%, optimized for minimum necessary deployments to reach 2688, is displayed in Appendix D.

IV. OPTIMIZATION

Having developed the MOE and a model to describe the relationship of the MOE to the various inputs, the next step was to find values of the decision variables that would result in an MOE value of less than 2688.

A. INPUTS

1. Fixed and Variable Parameters

As this study is structured, the forecast of Soviet ICBM and FBB development and deployment is a fixed parameter which determines a particular targeting surface in SBKKV x YEAR x RV space. While the threat forecast in this particular study would permit the consideration of the effects of variations in the Soviet FBB deployment rate after 1999,[22] any variation which involved other missile deployment rates, or FBB deployment rates before 1999, or changed the launch timing or sequencing, or changed the basing scheme, would require the generation of a new surface for the TARGET file.

The single shot p(k) of the KKV is a variable parameter which affects system effectiveness but is independent of the deployment rate. This p(k) may increase as a result of further development if the start of system deployment is delayed. This study will present results for p(k) = 0.9, 0.8, and 0.7 in order to demonstrate the sensitivity of the results to the KKV p(k) value.

Another parameter which can be varied in this study is the degree of confidence with which the SBKKV layer will be expected to perform. This study will present sample results for a defender wanting 99% confidence that his MOE level **will not** be exceeded, and for an attacker wanting 85% confidence that the defender's MOE level **will** be exceeded. Note that 85% confidence for the attacker is the equivalent of 15% confidence for the defender.

2. Decision Variables

The start date for deployment of SBKKV has a significant impact on the required rates of deployment to achieve the MOE. Once a threat forecast has been made, the total number of SBKKV required for each year of the forecast is determined. If the deployment date is delayed, there is no reason to expect the growth rate of the

---

[22]This is only because the inputs for this study assume that after 1999 only FBB will be deployed.

threat to slow. Delay in deployment start could allow such threat growth as to transform the deployment of sufficient SBKKV to meet it into an almost impossible task.

The other decision variables in this study are the annual rates of SBKKV platform deployment. Once the other parameters and the start date are set, these variables determine the number of SBKKV platforms in orbit for any given engagement, and thus the number of RV arriving in midcourse, in any particular year in the future. High deployment rates would certainly optimize the MOE, swiftly driving the number of RV penetrating the SBKKV layer to a very low level. However, there are other considerations.

In order to accomplish its mission, the SBKKV layer need not have zero leakage. It may permit up to a specified maximum number of RV to penetrate, based on the design capacity of the midcourse layer. Accordingly, an unnecessarily high deployment rate might result in a misallocation of national resources.

Another factor which may impact on the deployment rate is the production schedule for SBKKV and their platforms. Minimum required deployment rates may change up or down from year to year. It would not be desirable to have the production rates fluctuate widely. A gradual initiation of production would be preferable, followed by acceleration to peak production, and then a tapering off as the SBKKV are augmented by more advanced systems in the out-years.

B. STATEMENT OF THE PROBLEM

Minimize

$$\text{deployment rate}_i \quad (i = 1994\text{-}2004)$$

subject to

$$\text{RVPEN}_i - \text{required MOE level} <= 0$$

for all engagements after 11 months from start date

where

$$\text{RVPEN}_i = f(\text{deployment rate}_i, \text{previous deployments}, \text{confidence level, KKV } p(k), \text{surface, engagement year } i).$$

Note that if the deployment rate for the first year is zero, that necessarily implies a start date after that year. Note also that the constraint requires the attainment of the full effectiveness level in the very first year of deployments, and that the changing threat requires continuing deployments of SBKKV platforms to maintain that effectiveness level. Under these conditions, static terms such as IOC and FOC have little meaning.

The solution to this optimization problem is the minimum number of SBKKV platforms which would need to be deployed each year in order to meet the goals of the defense (whether that goal is minimum deterrence or a high degree of positive security). After these requirements are input to the programming and budgeting process, the problem may be transformed into minimizing RVPEN subject to limits on SBKKV platform deployment.[23]

C. BASIC RESULTS

The results displayed in Table 3 and Figure 4.1 show the minimum required deployment rates to achieve the defender's security goal of 99% confidence that the number of penetrating RV will be below 2688 by December 1994 and for each month thereafter until December 2004. It is immediately clear that a KKV with a p(k) of .7 is not worth its probable cost. A SBKKV system with a KKV p(k) of .8 would be able to accomplish the mission through the year 2000, but would require more than 20,000 KKV (2,000 platforms) in 2001. A system with a KKV p(k) of .9 would be able to accomplish the mission through 2004, but would require more than 20,000 KKV in 2005.

The results displayed in Table 4 and Figure 4.2 show the minimum required deployment rates to achieve the defender's deterrence goal of 15% confidence that the number of penetrating RV will be below 2688 by December 1994 and for each month thereafter until December 2004. Since it is generally easier to deny victory to an opponent than to ensure victory for oneself, it is not surprising that the deterrence mission requires fewer platforms. The useful lives of the KKV p(k) = .7 system and the KKV p(k) = .8 system are both extended two years, while the useful life of the KKV p(k) = .9 system will likely be extended through the year 2005.

Whatever the parameters, examination of the minimum required launches in the out-years (see Figures 4.1 and 4.2) indicates that, as increasing numbers of RV are launched on FBB to evade the SBKKV, greater numbers of SBKKV are required to intercept more of the RV from conventional ICBM. There is a diminishing marginal return on SBKKV deployment after the year 2000, due to the requirement to achieve more and more interceptions over a constant geographic area from a conventional booster target population that is no longer growing.

---

[23]This transformed problem resolves quickly into: Deploy as many platforms as available as soon as possible in order to reduce RVPEN as much as possible.

TABLE 3

MINIMUM REQUIRED PLATFORM DEPLOYMENTS TO ACHIEVE 2688
WITH 99% CONFIDENCE

YEAR	94	95	96	97	98	99	00	01	02	03	04
For KKV p(k) = 0.9:											
YEARLY	168	108	132	108	138	102	120	168	192	198	492
TOTAL	168	276	408	516	654	756	876	1044	1236	1434	1926
For KKV p(k) = 0.8 :											
YEARLY	198	150	180	234	234	276	216	594	over 2000		
TOTAL	198	348	528	762	996	1272	1488	****	in Nov 2001		
For KKV p(k) = 0.7 :											
YEARLY	246	228	396	516	1092	over 2000					
TOTAL	246	474	870	1386	****	in Jul 1998					

TABLE 4

MINIMUM REQUIRED PLATFORM DEPLOYMENTS TO ACHIEVE 2688
WITH 15% CONFIDENCE

YEAR	94	95	96	97	98	99	00	01	02	03	04
For KKV p(k) = 0.9:											
YEARLY	150	102	114	108	102	96	90	120	162	192	192
TOTAL	150	252	366	474	576	672	762	882	1044	1236	1428
For KKV p(k) = 0.8 :											
YEARLY	174	120	150	156	198	162	210	204	486	594	
TOTAL	174	294	444	600	798	960	1170	1374	1860	****	
For KKV p(k) = 0.7 :											
YEARLY	198	174	234	336	378	504	696	over 2000			
TOTAL	198	372	606	942	1320	1824	****	in Apr 2000			

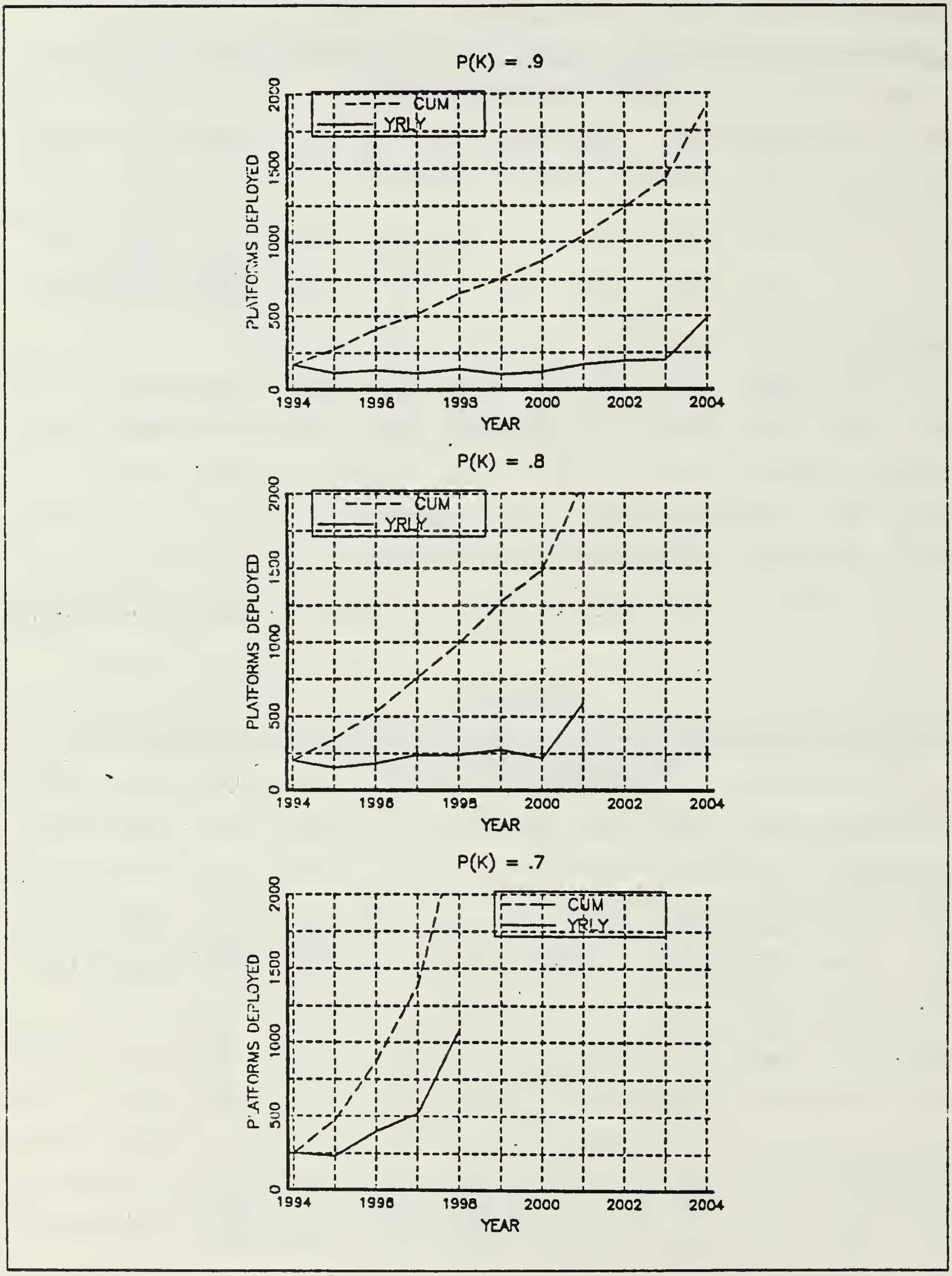

Figure 4.1 MINIMUM DEPLOYMENTS FOR 2688 WITH 99% CONFIDENCE.

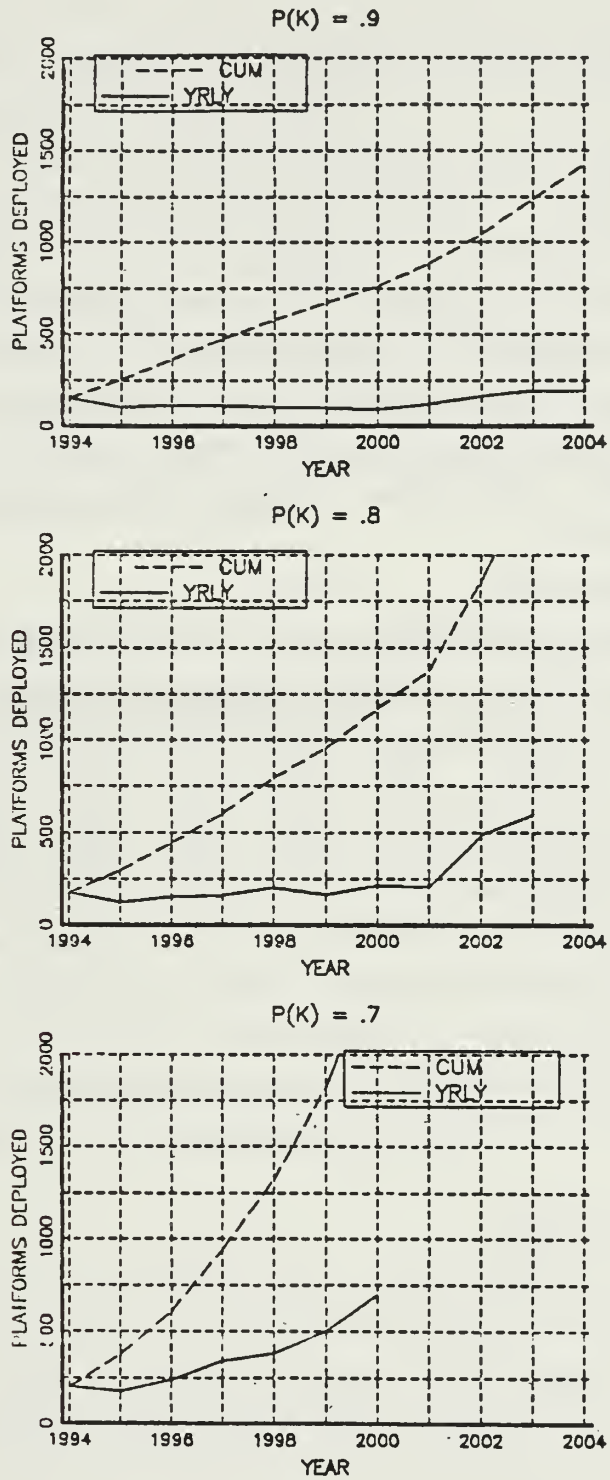

Figure 4.2 MINIMUM DEPLOYMENTS FOR 2688 WITH 15% CONFIDENCE.

D. EXTENSIONS

1. Delayed Start

The cumulative minimum deployment totals are not incidental sums of previous years' deployments, but are absolutely determined by the parameters of the targeting surface, the KKV p(k), and the confidence level. They are independent of the start date. A one year delay, to January 1995, would mean zero deployments in 1994, but the deferred 1994 deployments would have to be made up in order eventually to meet the cumulative minimum number of platforms required at the end of each year. It is not likely that the large number of platforms required by the end of 1995 could all be launched in 1995, and thus the constraint in the optimization problem would be violated. The goal date would have to be pushed back to the end of 1996, and thus a one-year delay in starting to deploy causes a two-year additional delay in reaching the desired level of effectiveness.[24]

2. "Smoothed" Deployments

Deploying at minimally effective rates has two disadvantages: It is inefficient and it is very sensitive to disruption or delay of the launch schedule. It also requires a large "down payment" in order to achieve the desired MOE level by the end of the first year of deployment. In order to reduce the strain on the production and launch systems at the beginning of deployment and to maintain efficient SBKKV production schedules, it may be acceptable to relax the 11-month goal-achievement constraint and to put off the MOE requirement for one year in order to smooth out the production and launch rates over the years of deployment. Table 5 and Figure 4.3 show how this might be done for the KKV p(k) = .9 system with a deterrence objective, accepting a delay until December 1995 in meeting the effectiveness requirement in order to gain smoother production and launch operations and provide a bit of deployment slack in the out-years.

3. Use of the Space Shuttle

If the SBKKV platforms were to be launched by the Shuttle, then the deployment rate of SBKKV per year would depend on the number of Shuttle launches per year with platforms aboard, and the number of platforms which could be carried on board a Shuttle. The Marshall Institute study assumes a KKV weight of 500

[24]For the p(k) = .9 system designed to deter, a one-year delay would call for 252 platforms deployed in 1995 to reach the MOE by the end of 1995, or a total of 366 platforms deployed in 1995 and 1996 to reach the MOE by the end of 1996. For less capable systems and/or more higher standards of performance, the difficulty is even greater.

pounds, and a platform weight per KKV carried also of 500 pounds [Ref. 3: p. 9]. For a 10 KKV per platform design, this implies 10,000 pounds for each complete platform. Given a Shuttle cargo capacity of 30 tons [Ref. 21: p. 196], then 6 complete KKV platforms could be lifted per Shuttle launched.[25]

The SDIO would not be the only Shuttle user: There will certainly be competition from commercial and scientific payloads for Shuttle capacity. If we assume that the original Shuttle launch schedule of 24 per year is eventually attained [Ref. 22: p. 102] (thus permitting 24 x 6 = 144 platforms per year to be deployed), then 144 is an upper bound on the SBKKV deployment rate. Only the KKV p(k) = .9 system deployed to achieve the deterrence goal would be feasible within that constraint, and then only with smoothing to reduce the requirements for launches in 1994, 2002, 2003, and 2004. See Table 5 and Figure 4.3

TABLE 5

SMOOTHED PLATFORM DEPLOYMENTS

For KKV p(k) = 0.9 and 15% confidence level:

YEAR	94	95	96	97	98	99	00	01	02	03	04
YEARLY	108	144	132	132	132	132	132	132	132	132	120
TOTAL	108	252	366	474	576	672	762	882	1044	1236	1428

[25]Although military equipment loaded aboard transport aircraft usually fills the available space before the aircraft's weight limit is reached, much of the volume in military vehicles is crew space. An SBKKV platform, needing no crew space, will require less volume per pound.

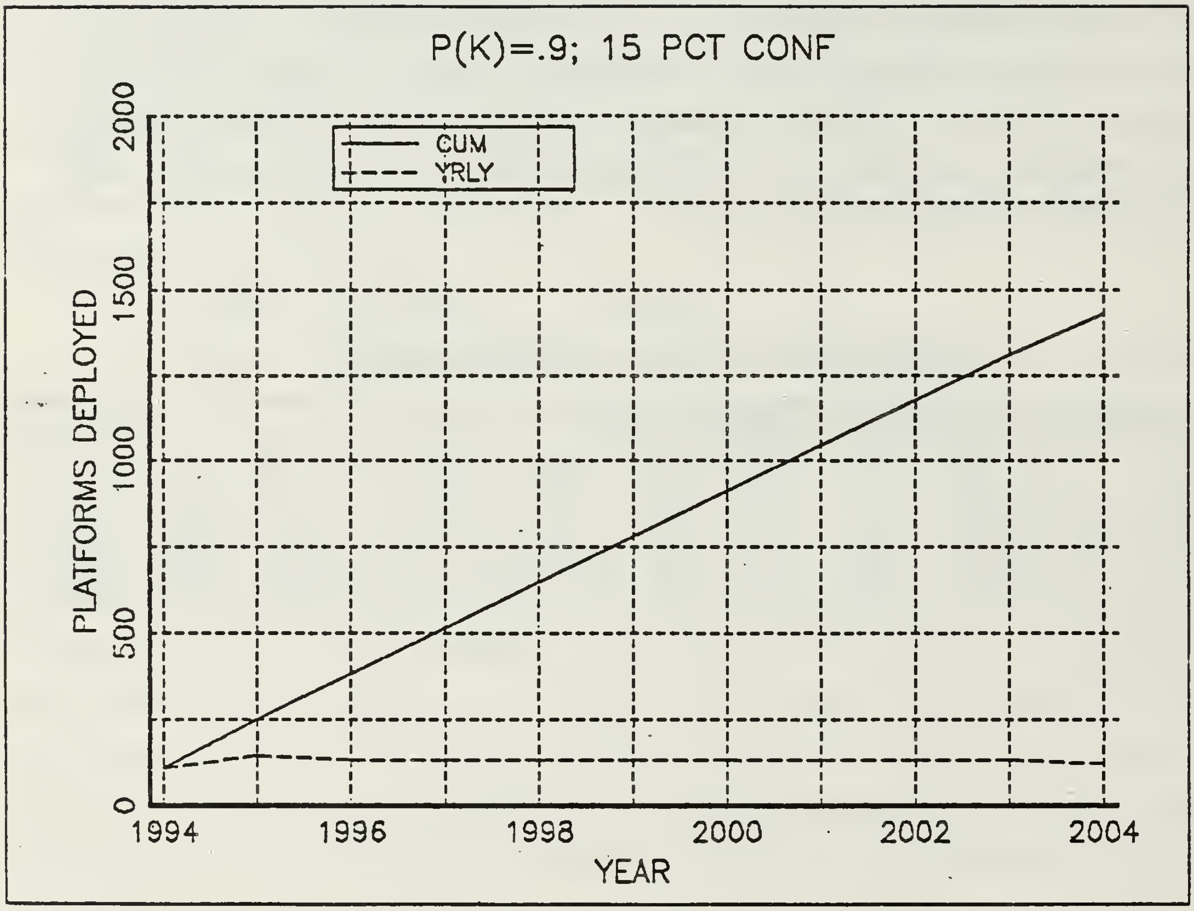

Figure 4.3 YEARLY AND CUMULATIVE SMOOTHED DEPLOYMENT.

V. CONCLUSIONS AND RECOMMENDATIONS

The measure of effectiveness for each layer of a BMD must be the absolute number of RV that penetrate it. Percentages do not remain constant: 90% of 5000 RV is only 45% of 10,000 RV, and a 90% that is sufficient in 199X will not be sufficient in 199X + 4. Furthermore, percentages are not real: Assumptions about the numbers and characteristics of future RV in possible attacks give designers and system architects something to work with, while requirements to intercept X% of attacking boosters give them a firm grasp of nothing. Percentages are interesting numbers derived from engagement simulation results, but should not drive architecture or system designs. It is worth noting that the mission to allow a maximum of 2688 RV (with 99% confidence) through the layer was accomplished in this study by the p(k) = .9 system by destroying between 39 and 72% of the RV launched at it, depending on the year.

When forecasting deployment requirements, the use of the expected value of system performance is inadequate. If the goal is positive control over security, the expected value approach will not require enough platforms. If the goal is merely reduction of an attacker's confidence of success, the expected value approach will require too many platforms. Random effects demand that one-sided confidence intervals be used to represent system performance.

Any decision to develop or deploy a BMD should consider system effectiveness throughout its lifetime. The p(k) = .7 system was initially capable, but in the face of a growing threat it became quickly unsatisfactory. The failure of an adversary to hold still has brought many a nation to grief in the past.

A year-by-year forecast of performance also alerts decisionmakers to potential problems. If the p(k) = .9 system were to be deployed at the minimum rate for the deterrence mission, it would be able to accomplish this mission throughout the 1994-2004 timeframe. Yet if the Shuttle were to be the primary launch system, then the mission could not be accomplished at minimum deployment rates in 1994 nor in the years 2002 and beyond. The forecast having signalled the problem in the out-years, it could be solved within the capabilities of the Shuttle schedule by smoothing and accelerating earlier deployments (see Table 5).

The results of this study indicate that the U.S. will have to vastly expand its space launch capacity by the time SBKKV deployments begin. Even a KKV p(k) = .9 system at the 15% confidence level would use 90% of the available Shuttle launches for 11 years. There must be, by 1994, alternate Medium and/or Heavy-Lift Launch Vehicles for SDIO's use. The methodology developed in this study to forecast deployment requirements can help drive the design and procurement of such systems by forecasting the amount of lift capacity needed over a period of time. Possible relief from this requirement could come from relaxation of the required level of effectiveness,[26] or by reducing the required degree of confidence in attaining the desired level of effectiveness, or by increasing the capability of the system, or if the threat were less. It should be remembered, however, that the threat scenario used for this study was not the worst possible case.

As was indicated by the increasing requirement for deployments to maintain RV penetration below 2688 after the year 2000, **introduction of FBB by the U.S.S.R. will eventually make a defense based on SBKKV too costly.** Although the SBKKV will have provided adequate protection for up to 10 years, by 2005 even a p(k) = .9 system will be inadequate for security. Some means will have to be found in the time bought by the SBKKV to defeat the FBB. Indeed, if it is discovered that KKV p(k) or overall system reliability will not be high enough, or deployments cannot be made soon or fast enough, or the threat is changing even faster, then SBKKV may not be as attractive as they seem today, and resources might be better employed to develop other technologies.

Serious ballistic missile defense will require a long-term national commitment to maintain production and deployment on schedule. The effects of a one-year delay in the start date demonstrate the consequences of failing to meet minimum requirements. Even for the p(k) = .9 system a deployment delayed would never be recovered without much greater launch and production capacity, and a decision to stretch out deployment "just one more year" would put an excessive and continuing burden on the downstream layers of the defense. The ultimate result would be more final leakage of nuclear warheads onto U.S. territory. This must be clearly understood by all those involved in the decision-making process through the lifetime of the system.

The procedure demonstrated in this study will enable analysts to quickly compare different systems and alternative futures for decision-makers. Given a threat forecast and any model of the performance of a BMD system or layer, an interception surface

---

[26]This would, of course, increase the load on the midcourse layer.

in WEAPON x YEAR x RV space can be generated, to whatever accuracy is desired or possible. Once this surface exists, the results of various deployment alternatives can be easily determined, and recommendations made.

APPENDIX A
GLOSSARY OF ACRONYMS

$BHIT_i$	number of boosters of category i intercepted by KKV
BMD	ballistic missile defense
$BTGT_i$	number of boosters of category i targeted by KKV
FBB	Fast-Burn booster
FO	follow-on (a successor ICBM to a previous model)
FOC	final operational capability
ICBM	intercontinental ballistic missile
IOC	initial operational capability
IR	infra-red
KKV	kinetic kill vehicle
MOE	measure of effectiveness
PBV	post-boost vehicle
P(K)	single-shot probability of kill
RV	reentry vehicle
RV_i	number of RV on a booster of category i
RVHIT	total number of RV destroyed by KKV interceptions
$RVHIT_i$	number of RV on boosters of category i destroyed by KKV
RVLNCH	total number of RV launched in an engagement
RVPEN	total number of RV which penetrate the SBKKV layer
RVTGT	total number of RV on targeted boosters
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Organization
SBKKV	space-based kinetic kill vehicle
SLBM	submarine-launched ballistic missile
SS	surface-to-surface (U.S. prefix: designates Soviet ICBM)

APPENDIX B
THREAT SCENARIO FOR BASIC MODEL

The ICBM mix which was input to the RAND model to generate the basic 36 data points is listed here. The total numbers of RV on each type of ICBM are listed in parentheses.

TABLE 6
BASIC THREAT FORECAST

Type	Year			
	1994	1995	1999	2004
SS-18	200 (2000)	200 (2000)	200 (2000)	200 (2000)
SS-19	240 (1440)	240 (1440)	240 (1440)	240 (1440)
SS-24	40 (400)	80 (800)	320 (3200)	320 (3200)
SS-25	120 (120)	180 (180)	200 (200)	200 (200)
SS-18FO	40 (400)	60 (600)	120 (1200)	120 (1200)
FBB	0 (0)	60 (180)	110 (330)	550 (1650)

APPENDIX C
PROGRAM AND INPUT FILES

```
C       SBKKV EFFECTIVENESS PROGRAM  --  SEPTEMBER 1987
C       CPT FREDERICK W. WEBER, JR., U.S. ARMY
C       NAVAL POSTGRADUATE SCHOOL
C       INPUT FILE DEFINITIONS:
C            FILEDEF 11 DISK TARGET DATA A
C            FILEDEF 12 DISK LAUNCH DATA A
C            FILEDEF 13 DISK DEPLRATE DATA A
C       OUTPUT FILE DEFINITION:
C            FILEDEF 14 DISK OUTPUT LISTING A
C       THIS PROGRAM CALCULATES AN UPPER LIMIT (GIVEN A SPECIFIC
C       STATISTICAL CONFIDENCE LEVEL) FOR THE NUMBER OF
C       ATTACKING NUCLEAR WARHEAD REENTRY VEHICLES WHICH WILL
C       PENETRATE A LAYER OF SATELLITE PLATFORMS CARRYING
C       SPACE-BASED KINETIC KILL VEHICLES.
C       THE PROGRAM DEPENDS ON THE INPUT FILE 'TARGET' WHICH REPRESENTS
C       A SURFACE IN SBKKV X YEAR X RV SPACE.
C       THE DATA IN THE 'TARGET' FILE CAN BE GENERATED BY ANY METHOD OR
C       MODEL ACCEPTABLE TO THE USER OF THIS PROGRAM.
C       THE 'LAUNCH' FILE CONTAINS DATA DESCRIBING THE NUMBER AND BOOSTER
C       MIX OF THE ATTACKING RV FOR THE YEARS OF THE FORECAST WHICH WAS
C       USED TO GENERATE THE 'TARGET' SURFACE.
C       THE 'DEPLRATE' FILE CONTAINS DATA DESCRIBING THE YEARLY DEPLOYMENT
C       RATES OF THE SBKKV PLATFORMS.
C       THE PROGRAM IS PRESENTED HERE WITH A DEPLOYMENT START DATE OF
C       JANUARY 1994 AND A KKV P(K) OF 0.9.  THESE VALUES MAY BE CHANGED
C       TO REFLECT A DIFFERENT SCENARIO.
C       AFTER PROGRAM EXECUTION, THE OUTPUT FILE WILL CONTAIN, FOR EACH
C       MONTH, THE TOTAL NUMBER OF SBKKV PLATFORMS ON STATION, THE
C       TOTAL NUMBER OF RV WHICH COULD BE LAUNCHED ACCORDING TO THE
C       THREAT SCENARIO, THE AVERAGE NUMBER OF RV WHICH WOULD PENETRATE
C       THE LAYER, THE MAXIMUM NUMBER (FOR THE GIVEN CONFIDENCE LEVEL)
C       OF RV WHICH WOULD PENETRATE THE LAYER, AND THE YEAR IN WHICH
C       THE ENGAGEMENT OCCURRED.
C       INPUT:
C       THE 'TARGET' FILE CONTAINS 21 ROWS (REFLECTING 0 TO 2000 SBKKV
C       PLATFORMS, IN INCREMENTS OF 100) AND 12 COLUMNS (REFLECTING THE
C       YEARS 1993-2004).  ITS CELLS CONTAIN THE NUMBERS OF WARHEADS WHICH
C       WOULD BE TARGETED BY A SBKKV LAYER OF GIVEN CAPABILITIES
C       IF A GIVEN ATTACK WERE TO TAKE PLACE IN THE YEAR AND AGAINST
C       THE NUMBER OF SBKKV WHICH INDEX EACH CELL.
C       THE 'LAUNCH' FILE CONTAINS THE NUMBER OF ATTACKING RV FORECAST
C       FOR EACH CATEGORY OF MISSILE IN EACH YEAR OF THE SCENARIO.  DUE TO
C       THE PARTICULAR CHARACTERISTICS OF THE TARGET DATA SOURCE MODEL,
C       RV ARE NOT CLASSIFIED IN THIS PROGRAM BY SPECIFIC ICBM MODEL, BUT
C       ONLY BY THE NUMBER OF RV CARRIED ABOARD THE ICBM (THUS, RV FROM
C       THE 10-WARHEAD SS-18 AND SS-24 ARE LUMPED TOGETHER IN THIS FILE).
C       THE 'DEPLRATE' FILE CAN BE CHANGED TO REFLECT DIFFERENT
C       DEPLOYMENT SCHEDULES IN ORDER TO EXPLORE THEIR EFFECTS ON THE
C       EFFECTIVENESS OF THE LAYER.
C       OTHER USER-DETERMINED INPUTS ARE THE KKV P(K), THE CONFIDENCE
C       LEVEL TO BE USED, AND THE STARTING YEAR.  THESE VALUES ARE SET
C       BY CHANGING THE VALUES IN THE DATA STATEMENT.
C       THE DETAILS OF THE ALGORITHM ARE DISCUSSED IN THE COMMENTS AT
C       EACH STATEMENT.
```

```
C     GLOSSARY OF VARIABLE NAMES:
C     A = FRACTIONS OF A YEAR.  USED FOR INTERPOLATION AT 140, 160
C     AVPEN(I) = EXPECTED VALUE OF NUMBER OF RV PENETRATING THE
C             LAYER IN A GIVEN ENGAGEMENT I
C     B = FRACTIONS OF 100 PLATFORMS.  USED FOR INTERPOLATION AT 160
C     COL = IDENTIFIES CORRECT COLUMN IN LAUNCH AND TARGET DATA FILES
C     DPLOYD(I) = REAL NUMBER OF SBKKV PLATFORMS DEPLOYED
C     ERVHIT = EXPECTED NUMBER OF RV DESTROYED
C     INDEX = ABSOLUTE NUMBER OF THE MONTH BEFORE DEPLOYMENTS START
C     KOUNT = ABSOLUTE NUMBER OF THE MONTH FOR WHICH A RESULT IS
C             BEING CALCULATED
C     LAUNCH(I,J) = NUMBER OF RV LAUNCHED IN YEAR I
C             BY CATEGORY OF ICBM J
C     LNCH1 = NUMBER OF RV LAUNCHED ON SS-25'S
C     LNCH3 = NUMBER OF RV LAUNCHED ON FBB'S
C     LNCH6 = NUMBER OF RV LAUNCHED ON SS-19'S
C     LNCH10 = NUMBER OF RV LAUNCHED ON SS-18'S, SS-24'S, SS-18FO'S
C     MAXPEN(I) = UPPER BOUNDARY OF CONFIDENCE INTERVAL FOR RVPEN
C     MINHIT = LOWER BOUNDARY OF CONFIDENCE INTERVAL FOR NUMBER OF
C             RV DESTROYED.
C     MINPEN = NUMBER OF RV THAT GET CLEAN AWAY WITHOUT EVEN
C             BEING TARGETED
C     MONTH = WITHIN 'YEAR,' THE MONTH THAT DEPLOYMENTS BEGIN
C     P = INDIVIDUAL KKV PROBABILITY OF KILL, GIVEN FIRED AT A BOOSTER
C     RATE(I) = NUMBER OF SBKKV PLATFORMS LAUNCHED IN A GIVEN YEAR
C     RVLNCH(I) = NUMBER OF RV LAUNCHED IN A GIVEN ATTACK WITHIN A YEAR
C     RVTGT = TOTAL NUMBER OF RV ON ALL TARGETED ICBM
C     SOFAR(I) = INTEGER NUMBER OF SBKKV PLATFORMS DEPLOYED IN MONTH I
C     START = YEAR AND MONTH OF START OF DEPLOYMENTS.  NOVEMBER 1995
C             WOULD BE 1995.11
C     TARGET(I,J) = NUMBER OF RV ON BOARD ICBM TARGETED BY KKV, IN
C               YEAR I AND FOR A GIVEN NUMBER J OF SBKKV PLATFORMS
C     TGT1 = NUMBER OF TARGETED ICBM CARRYING 1 RV (I.E., SS-25)
C     TGT6 = NUMBER OF ICBM CARRYING 6 RV (I.E., SS-19)
C     TGT10 = NUMBER OF ICBM CARRYING 10 RV (I.E., SS-18, SS-24, SS-18FO
C     VRVHIT = VARIANCE OF NUMBER OF RV DESTROYED
C     YEAR = YEAR THAT SBKKV PLATFORM DEPLOYMENTS BEGIN
C     Z = VALUE OF THE STANDARD NORMAL RANDOM VARIABLE CORRESPONDING TO
C             THE DESIRED CONFIDENCE INTERVAL
C     THERE IS NO TGT3 VARIABLE, AS THE MODEL INDICATED THAT NO FBB
C             WOULD EVER GET HIT.


   10  INTEGER AVPEN, COL, INDEX, LNCH1, LNCH3, LNCH6, LNCH10, MAXPEN,
      1MINPEN, MONTH, ROW, RVLNCH, RVTGT, SOFAR, TARGET, TGT1, TGT6,
      2TGT10, YEAR
   20  REAL A, B, DPLOYD, ERVHIT, P, RATE, START, VRVHIT, Z
C     DIMENSIONING STARTS WITH 0TH ELEMENTS TO ALLOW FOR CONDITIONS
C     PRIOR TO 1994 OR WHEN 0 SBKKV PLATFORMS HAVE BEEN DEPLOYED.
   30  DIMENSION DPLOYD(0:132), HISURV(0:132), LAUNCH(1:4,0:11),
      1 RATE(1994:2005), TARGET(0:20,0:11),SOFAR(0:132),RVLNCH(0:132),
      2AVPEN(0:132), MAXPEN(0:132)

C     INPUTS CAN BE MODIFIED HERE.
   40  DATA P/0.9/, Z/2.327/, START/1994.01/

   50  READ (11, '(12I5)') ((TARGET(I,J), J=0,11), I=0,20)
        READ (12, '(12I5)') ((LAUNCH(I,J), J=0,11), I=1,4)
        READ (13, '(12F5.1)') (RATE(I), I=1994,2005)

C     IF EXPLORING VARIOUS ALTERNATIVES AFTER SOME NUMBER OF
C     PLATFORMS ALREADY HAVE BEEN DEPLOYED, THESE VARIABLES SHOULD
C     BE INITIALIZED AT THAT NUMBER, RATHER THAN ZERO.
```

```
   60  DPLOYD(0) = 0.
        SOFAR(0) = 0

C      THE START DATE CAN BE VARIED TO EXPLORE DIFFERENT ALTERNATIVES.
C      THE VARIABLES 'YEAR' AND 'MONTH' ONLY APPEAR HERE.  THEIR PURPOSE
C      IS ONLY TO CLARIFY THE DERIVATION OF THE VARIABLE 'INDEX.'
C      THE VARIABLE 'INDEX' SETS A REFERENCE MONTH BETWEEN DECEMBER 1993
C      AND DECEMBER 2004 FOR COUNTING PURPOSES.
   70  YEAR = INT(START)
        MONTH = NINT(100 * (START - YEAR))
        INDEX = (12 * YEAR) + MONTH - 1

C      THIS LOOP GENERATES THE CUMULATIVE NUMBER OF SBKKV PLATFORMS
C      DEPLOYED IN ANY MONTH BETWEEN THE START OF DEPLOYMENTS AND
C      DECEMBER 2004.  24060 IS EXACTLY 12 X 2005.  2005 IS THE
C      LIMIT BECAUSE THE THREAT FORECAST ONLY EXTENDS TO 2004.
C      FOR A FORECAST ENDING OTHER THAN IN 2004, THIS VALUE WOULD
C      BECOME: 12 X (END YEAR + 1).
   80  DO 90 KOUNT = INDEX, 24060
           DPLOYD(1+KOUNT-INDEX) = (RATE(KOUNT/12) / 12.)
     1                                               + DPLOYD(KOUNT-INDEX)
           SOFAR(1+KOUNT-INDEX) = NINT(DPLOYD(1+KOUNT-INDEX))
   90  CONTINUE

C      THIS LOOP GENERATES THE NUMBER OF RV PENETRATING THE SBKKV LAYER.
C      THIS LOOP CYCLES ONCE FOR EACH MONTH BETWEEN THE START OF
C      DEPLOYMENT AND THE LIMITS OF THE RV DESTRUCTION DATA.
  110  DO 250 KOUNT = INDEX, 24060

C      THIS STOPS THE CYCLING WHEN THE NUMBER OF PLATFORMS EXCEEDS 2000.
  120     IF (SOFAR(KOUNT-INDEX) - 2000) 130, 130, 260

C      THESE VALUES ARE CALCULATED TO SIMPLIFY THE INTERPOLATIONS IN
C      STATEMENTS 140 AND 160
  130     COL = (KOUNT / 12) - 1994
            A = MOD(KOUNT, 12) / 12.
            ROW = SOFAR(KOUNT-INDEX) / 100
            B = (SOFAR(KOUNT-INDEX) - 100 * ROW)/ 100.

C      THESE ARE THE MONTHLY INTERPOLATIONS FOR RV LAUNCHED.
  140     LNCH1 = NINT(((1 - A) * LAUNCH(4,COL)) + (A * LAUNCH(4,COL+1)))
            LNCH3 = NINT(((1 - A) * LAUNCH(3,COL)) + (A * LAUNCH(3,COL+1)))
            LNCH6 = NINT(((1 - A) * LAUNCH(2,COL)) + (A * LAUNCH(2,COL+1)))
            LNCH10 = NINT(((1 - A) * LAUNCH(1,COL)) + (A* LAUNCH(1,COL+1)))
            RVLNCH(KOUNT-INDEX) = LNCH1 + LNCH3 + LNCH6 + LNCH10


C      THIS IS THE FOUR-POINT INTERPOLATION REFERRED TO IN CHAPTER III,
C      SECTION C, SUBSECTION 2 "PROGRAMMING."
  160     RVTGT = NINT((TARGET(ROW,COL) * (1. - A - B + (A * B)))
     1           + (TARGET(ROW,COL + 1) * (A - (A * B)))
     2           + (TARGET(ROW + 1,COL) * (B - (A * B)))
     3           + (TARGET(ROW + 1,COL + 1) * (A * B)))

  170     MINPEN = RVLNCH(KOUNT-INDEX) - RVTGT

  180     IF (MINPEN .GE. (LNCH3 + LNCH1 + LNCH6)) THEN
C      ONLY 10-RV BOOSTERS HAVE BEEN TARGETED.
                   TGT1 = 0
                   TGT6 = 0
```

```
               TGT10 = NINT((LNCH10 -
     1                   (MINPEN - (LNCH3 + LNCH1 + LNCH6))) / 10.)
               GO TO 240

190      ELSE IF (MINPEN .GE. (LNCH3 + LNCH1)) THEN
C     ALL 10-RV AND SOME 6-RV BOOSTERS HAVE BEEN TARGETED.
               TGT1 = 0
               TGT6 = NINT((LNCH6 - (MINPEN - (LNCH3 + LNCH1))) / 6.)
               TGT10 = NINT(LNCH10 / 10.)
               GO TO 240

200      ELSE
C     ALL 10-RV AND 6-RV, AND SOME 1-RV, HAVE BEEN TARGETED
               TGT1 = LNCH1 - (MINPEN - LNCH3)
               TGT6 = NINT(LNCH6 / 6.)
               TGT10 = NINT(LNCH10 / 10.)
         ENDIF

C     HERE ARE CALCULATED THE PARAMETERS OF THE NORMAL RANDOM VARIABLE
C     RVHIT.  THESE ARE USED TO DETERMINE THE AVERAGE AND MAXIMUM NUMBER
C     OF RV WHICH PENETRATE THE LAYER.
 240  ERVHIT = P * ((10 * TGT10) + (6 * TGT6) + TGT1)
       VRVHIT = P * (1 - P) * ((100 * TGT10) + (36 * TGT6) + TGT1)
       AVPEN(KOUNT-INDEX) = NINT(RVLNCH(KOUNT-INDEX) - ERVHIT)
       MAXPEN(KOUNT-INDEX) = RVLNCH(KOUNT-INDEX) -
     1                           NINT(ERVHIT - (Z * SQRT(VRVHIT)))

C     END OF LOOP
 250  CONTINUE

C     SET UP OUTPUT HEADINGS
 260  WRITE(14, 270)

C     NOTE THAT THE COLUMN LISTED AS MAXPEN WILL BECOME MINHIT IF Z
C     IS LESS THAN ZERO.
 270  FORMAT('0', 'PLATFORMS  RVLAUNCH  AVPEN   MAXPEN   YEAR')

C     OUTPUT
 280  WRITE(14, 290) (SOFAR(I), RVLNCH(I), AVPEN(I), MAXPEN(I),
     1 (YEAR + ((I - 1) / 12)), I = 1, KOUNT-INDEX-1)
 290  FORMAT (' ', I6, I10, I10, I8, I8)

       STOP
       END
```

The following is the TARGET DATA file referred to in the program. It contains the 220 points developed from the original 36, as well as a column of 0 RV targeted for 1993 and a row of 0 RV targeted when no KKV are deployed.

```
0    0    0    0    0    0    0    0    0    0    0    0
0 1340 1340 1350 1370 1400 1440 1440 1440 1440 1440 1440
0 2330 2340 2373 2429 2508 2610 2610 2610 2610 2610 2610
0 3040 3130 3240 3370 3520 3690 3690 3690 3690 3690 3690
0 3435 3622 3840 4090 4372 4684 4684 4684 4684 4684 4684
0 3700 3990 4314 4672 5064 5490 5490 5490 5490 5490 5490
0 3887 4223 4602 5024 5490 5998 5998 5998 5998 5998 5998
0 4010 4370 4783 5249 5768 6340 6340 6340 6340 6340 6340
0 4113 4530 4993 5501 6055 6654 6654 6654 6654 6654 6654
0 4191 4637 5126 5659 6234 6853 6853 6853 6853 6853 6853
0 4260 4750 5274 5832 6424 7050 7050 7050 7050 7050 7050
0 4299 4805 5347 5925 6539 7189 7189 7189 7189 7189 7189
0 4329 4868 5441 6047 6687 7360 7360 7360 7360 7360 7360
0 4340 4900 5497 6131 6802 7510 7510 7510 7510 7510 7510
0 4345 4941 5570 6233 6932 7665 7665 7665 7665 7665 7665
0 4350 4950 5591 6273 6996 7760 7760 7760 7760 7760 7760
0 4352 4964 5616 6309 7041 7814 7814 7814 7814 7814 7814
0 4354 4978 5641 6344 7086 7868 7868 7868 7868 7868 7868
0 4356 4992 5667 6380 7132 7922 7922 7922 7922 7922 7922
0 4358 5006 5692 6415 7177 7976 7976 7976 7976 7976 7976
0 4360 5020 5717 6451 7222 8030 8030 8030 8030 8030 8030
```

The following is the LAUNCH DATA input file which contains the number of warheads launched on each aggregate type of ICBM (10, 6, 3, or 1) for each year from 1993 to 2004.

```
2400  2800  3400  4170  4900  5660  6400  6400  6400  6400  6400  6400
1440  1440  1440  1440  1440  1440  1440  1440  1440  1440  1440  1440
   0     0   180   216   255   291   330   594   858  1122  1386  1650
  60   120   180   185   190   195   200   200   200   200   200   200
```

The input file DEPLRATE DATA contains whatever deployment sequence the analyst wishes to examine. The output in Appendix C was generated from the above program with the following DEPLRATE DATA file:

```
168.  108.  132.  108.  138.  102.  120.  168.  192.  198.  492.  00.
```

APPENDIX D
SAMPLE OUTPUT FROM PROGRAM

This appendix presents the output of the program when the deployment rates for the p(k) = .9 system are minimized while still achieving 99% confidence that the security goal of 2688 RVPEN will be achieved.

PLATFORMS	RVLAUNCH	AVPEN	MAXPEN	YEAR
14	3938	3920	3930	1994
28	3977	3923	3940	1994
42	4015	3889	3915	1994
56	4053	3828	3863	1994
70	4092	3741	3785	1994
84	4130	3626	3678	1994
98	4168	3475	3536	1994
112	4207	3334	3403	1994
126	4245	3165	3241	1994
140	4283	2978	3062	1994
154	4322	2774	2866	1994
168	4360	2551	2650	1994
177	4430	2540	2641	1995
186	4500	2529	2632	1995
195	4570	2518	2623	1995
204	4640	2516	2623	1995
213	4710	2523	2632	1995
222	4780	2530	2640	1995
231	4850	2537	2649	1995
240	4920	2544	2657	1995
249	4990	2542	2657	1995
258	5060	2549	2666	1995
267	5130	2556	2674	1995
276	5200	2554	2674	1995
287	5267	2531	2653	1996
298	5335	2518	2642	1996
309	5403	2523	2648	1996
320	5471	2528	2654	1996
331	5538	2532	2660	1996
342	5606	2537	2666	1996
353	5673	2532	2662	1996
364	5740	2536	2668	1996
375	5809	2533	2666	1996
386	5876	2528	2663	1996
397	5944	2524	2660	1996
408	6011	2519	2657	1996
417	6075	2529	2668	1997
426	6140	2531	2671	1997
435	6205	2533	2674	1997
444	6269	2534	2676	1997
453	6333	2535	2678	1997
462	6399	2538	2683	1997
471	6463	2530	2676	1997
480	6527	2531	2678	1997
489	6592	2524	2672	1997
498	6655	2515	2665	1997
507	6721	2518	2669	1997
516	6785	2528	2680	1997
528	6851	2522	2675	1998
539	6919	2527	2681	1998
551	6985	2521	2676	1998
562	7052	2516	2673	1998

574	7119	2511	2669	1998
585	7186	2506	2665	1998
597	7252	2500	2660	1998
608	7319	2495	2657	1998
620	7386	2499	2662	1998
631	7452	2502	2666	1998
643	7520	2507	2672	1998
654	7586	2510	2676	1998
663	7651	2512	2679	1999
671	7716	2514	2682	1999
680	7782	2512	2681	1999
688	7848	2513	2683	1999
697	7912	2512	2683	1999
705	7979	2514	2686	1999
714	8044	2514	2687	1999
722	8108	2514	2687	1999
731	8174	2506	2681	1999
739	8239	2506	2682	1999
748	8305	2507	2684	1999
756	8370	2507	2685	1999
766	8392	2497	2675	2000
776	8414	2492	2670	2000
786	8436	2487	2665	2000
796	8458	2482	2661	2000
806	8480	2482	2661	2000
816	8502	2483	2662	2000
826	8524	2489	2668	2000
836	8546	2494	2674	2000
846	8568	2495	2674	2000
856	8590	2501	2680	2000
866	8612	2506	2686	2000
876	8634	2507	2687	2000
890	8656	2507	2687	2001
904	8678	2502	2683	2001
918	8700	2503	2683	2001
932	8722	2498	2678	2001
946	8744	2493	2674	2001
960	8766	2493	2674	2001
974	8788	2488	2670	2001
988	8810	2488	2670	2001
1002	8832	2483	2665	2001
1016	8854	2489	2671	2001
1030	8876	2495	2677	2001
1044	8898	2495	2678	2001
1060	8920	2501	2684	2002
1076	8942	2502	2684	2002
1092	8964	2502	2685	2002
1108	8986	2502	2686	2002
1124	9008	2503	2686	2002
1140	9030	2498	2681	2002
1156	9052	2493	2677	2002
1172	9074	2493	2677	2002
1188	9096	2488	2672	2002
1204	9118	2489	2673	2002
1220	9140	2489	2674	2002
1236	9162	2489	2674	2002
1253	9184	2490	2675	2003
1269	9206	2490	2675	2003
1286	9228	2485	2671	2003
1302	9250	2486	2671	2003
1319	9272	2486	2672	2003
1335	9294	2486	2672	2003
1352	9316	2481	2668	2003
1368	9338	2482	2668	2003
1385	9360	2482	2669	2003
1401	9382	2483	2669	2003
1418	9404	2488	2675	2003
1434	9426	2500	2687	2003
1475	9448	2484	2671	2004
1516	9470	2479	2666	2004

1557	9492	2479	2667	2004
1598	9514	2480	2668	2004
1639	9536	2485	2674	2004
1680	9558	2487	2675	2004
1721	9580	2489	2677	2004
1762	9602	2491	2679	2004
1803	9624	2492	2681	2004
1844	9646	2495	2683	2004
1885	9668	2497	2685	2004
1926	9690	2499	2687	2004

APPENDIX E
GRAPHIC PLANNING TOOL

The initial insight of Section III-A can be extended to provide a graphic estimate of SBKKV platform deployment requirements, using two first quadrants which share a common axis.

The surface of RV penetrating the SBKKV layer, described in SBKKV x YEAR x RV space, can be projected into the SBKKV x RV plane as a set of level curves labelled by year. This occurs in a first quadrant because all values are positive, with SBKKV as the X-axis, and RVPEN as the Y-axis. The total number of SBKKV needed in any particular year can be derived by extending a line from the maximum permissible level of RVPEN parallel to the SBKKV axis. The intersections of this line with the labelled level curves will have coordinates ($SBKKV_{year}$, RVPENMAX), thus identifying for each year the number of SBKKV required.

If this "first" first quadrant were to be rotated 90 degrees counterclockwise, the SBKKV axis would become the Y-axis for a "second" first quadrant graph, with YEAR as the new positive X-axis. The $SBKKV_{year}$ points on the SBKKV axis could be used to identify points with coordinates (YEAR, $SBKKV_{year}$) in the YEAR x SBKKV quadrant. The trace of these points graphically illustrates the pace of SBKKV deployment required.

This relationship is demonstrated in Figure E.1 with the assumption of p(k) = 1.0, that is RVPEN = RVLNCH − RVTGT. Yet it would not be too difficult to generate level curves in the SBKKV x RV plane from the program in Appendix C which reflected a p(k) less than 1.0 and a desired confidence level.

This sort of graphic display would be of greatest value when demonstrating to decisionmakers the direct consequences for RVPEN from their decisions about deployment rates.

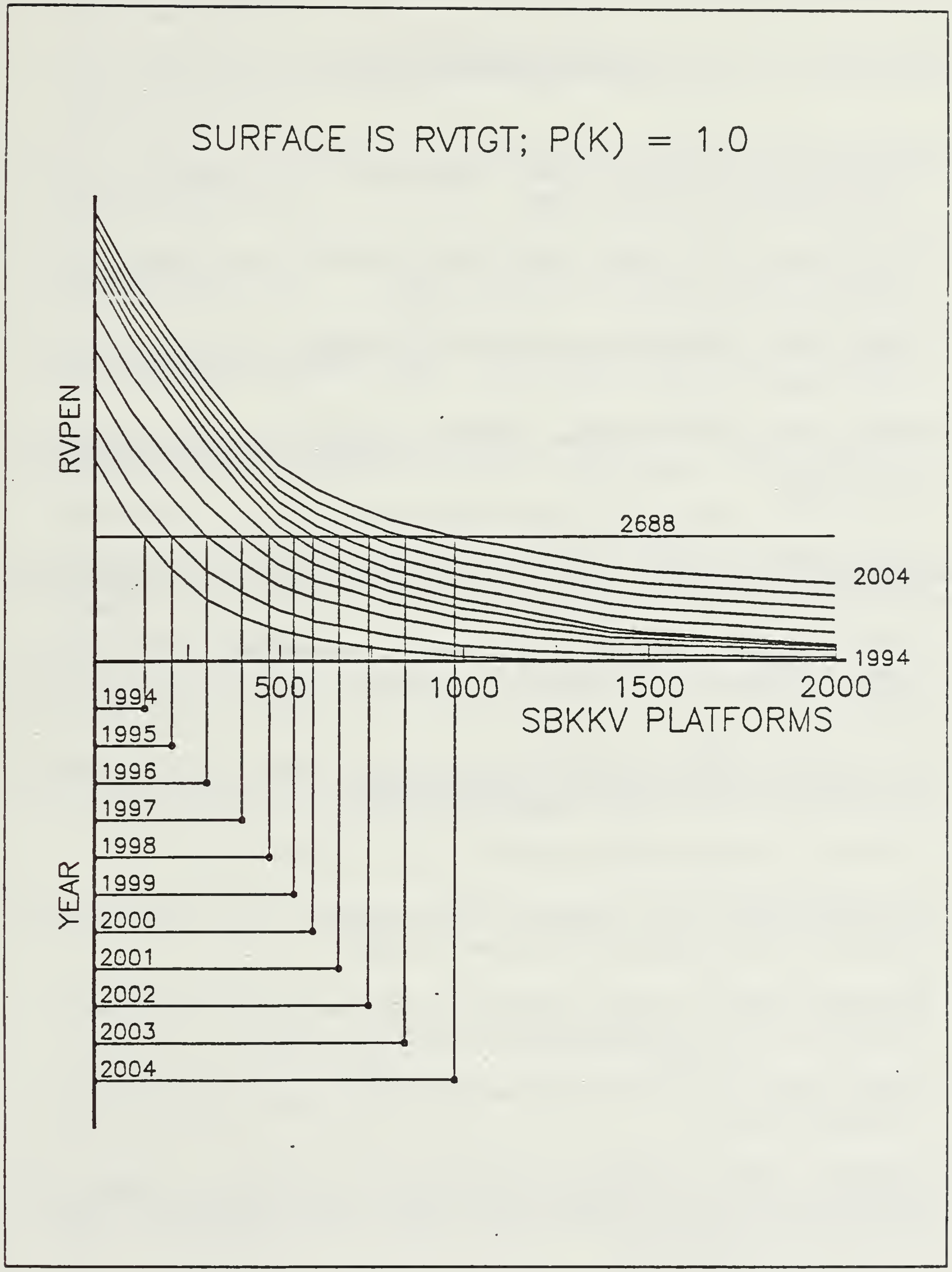

Figure E.1 GRAPHIC PLANNING TOOL.

LIST OF REFERENCES

1. "The President's Speech on Military Spending and a New Defense," *The New York Times*, p. A20, March 23, 1983.

2. U.S. Department of Defense, *Report to the Congress on the Strategic Defense Initiative*, U.S. Government Printing Office, 1986.

3. Gardner, John and others, *Report of the Technical Panel on Missile Defense in the 1990s*, George C. Marshall Institute, 1987.

4. O'Lone, Richard G., "Weinberger Foresees No Technical Blocks to First-Phase SDI Deployment," *Aviation Week & Space Technology*, Vol. 126, No. 19, p. 103, May 11, 1987.

5. Biddle, Wayne, "Star Wars: The Dream Diminished," *Discover*, Vol. 8, No. 7, pp. 26-38, July 1987.

6. Lafont, Duane M., *An Evaluation of Potential Countermeasures to the Strategic Defense Initiative*, M.S. Thesis, Naval Postgraduate School, Monterey, CA, March 1986.

7. U.S. Congress, Office of Technology Assessment, *Ballistic Missile Defense Technologies*, U.S. Government Printing Office, 1985.

8. "SDI Watch," *National Review*, Vol. 39, No. 4, p. 17, March 13, 1987.

9. Budiansky, Stephen, "The hardware of early deployment," *U.S. News & World Report*, Vol. 102, No. 7, pp. 28-29, February 23, 1987.

10. Rockower, Edward B., *Notes on Measures of Effectiveness*, Operations Research Department, Naval Postgraduate School, Monterey, CA, 1985.

11. Mizrahi, Maurice M., "In Search of the Holy MOE," *Phalanx*, Vol. 18, No. 3, p. 17, September 1985.

12. Cerwonka, Robert J., *Political Considerations in Developing Measures of Effectiveness for Strategic Defenses*, M.S. Thesis, Naval Postgraduate School, Monterey, CA, March, 1986.

13. Samuelson, Douglas A., "The Fireman's Parable," *OR/MS Today*, Vol. 14, No. 3, p. 11, June 1987.

14. U.S. Department of Defense, *Soviet Military Power*, 6th ed., U.S. Government Printing Office, 1987.

15. U.S. Department of Defense, *Soviet Military Power*, 3d ed., U.S. Government Printing Office, 1984.

16. U.S. Department of Defense, *Soviet Military Power*, 2d ed., U.S. Government Printing Office, 1983.

17. Scheder, Robert A., "Kinetic Energy Weapons Rank High," *Phalanx*, Vol. 19, No. 3, pp. 24-26, September 1986.

18. Miller, Michael, RAND Corporation, Santa Monica, CA, personal communication, 1-2 July 1987.

19. *GRAFSTAT Introductory Manual*, IBM Research, June 1986.

20. Abramowitz, Milton and Stegun, Irene, eds., *Handbook of Mathematical Functions with Formulas, Graphs, and Mathematical Tables*, U.S. Government Printing Office, 1964.

21. Tsipis, Kosta, *Arsenal: Understanding Weapons in the Nuclear Age*, Simon & Schuster, 1983.

22. Powers, Thomas, "Will Star Wars Work? It Isn't a Question of Technology," *Discover*, Vol. 7, No. 12, pp. 98-102, December 1986.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, VA 22304-6145	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, CA 93943-5002	2
3.	Professor E.B. Rockower, Code 55Rf Department of Operations Research Naval Postgraduate School Monterey, CA 93943-5000	2
4.	Professor B. Neta, Code 53Nd Department of Mathematics Naval Postgraduate School Monterey, CA 93943-5000	3
5.	Professor P. Purdue, Code 55Pd Department of Operations Research Naval Postgraduate School Monterey, CA 93943-5000	1
6.	Professor H. Fredricksen, Code 53Fs Department of Mathematics Naval Postgraduate School Monterey, CA 93943-5000	1
7.	Professor K. Woehler, Code 61Wh Department of Physics Naval Postgraduate School Monterey, CA 93943-5000	1
8.	Professor M.G. Sovereign, Code 55Sm Department of Operations Research Naval Postgraduate School Monterey, CA 93943-5000	1
9.	Professor C. Jones, Code 54Js Department of Administrative Sciences Naval Postgraduate School Monterey, CA 93943-5000	1

10. Professor J. Sternberg, Code 56Sn 1
Department of National Security Affairs
Naval Postgraduate School
Monterey, CA 93943-5000

11. Dr. Louis C. Marquet 3
Deputy for Technology
Strategic Defense Initiative Organization
The Pentagon
Washington, D.C. 20301-7100

12. Strategic Defense Initiative Organization 3
ATTN: SDIO-S (LTC Wayne K. Murphy)
The Pentagon
Washington, D.C. 20301-7100

13. Dr. Michael Miller 5
The RAND Corporation
1700 Main Street
Santa Monica, CA 90406

14. Mr. Timothy Webb 1
The RAND Corporation
2100 M Street, N.W.
Washington, D.C. 20037-1270

15. Mr. Thomas Morgan, L86 1
Lawrence Livermore National Laboratory
P.O. Box 808
Livermore, CA 94550

16. Mr. John Lawton 1
Naval Surface Weapons Center
Dahlgren, VA 22448

17. Dr. Maile Smith 1
Science and Technology Division
Institute for Defense Analyses
1801 North Beauregard Street
Alexandria, VA 22311

18. CPT(P) F.W. Weber, Jr. 9
C3CM JTF / USA Elm
Kirtland AFB, NM 87117

19. Mr. Troy Crites, M7/597 2
The Aerospace Corporation
P.O. Box 92957
Los Angeles, CA 90009

Thesis
W331 Weber
c.1 The impact of deployment rates on the effectiveness of strategic defenses.